STEWART

The Methods Used in Primary Level & Triangulation Work in Unsettled & Broken Country

Civil Engineering

C. E.

1909

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THE METHODS USED IN PRIMARY LEVEL AND TRIANGULATION WORK IN UNSETTLED AND BROKEN COUNTRY

BY

JOHN TRUESDALE STEWART

B. S., University of Illinois, 1893

THESIS

Submitted in Partial Fulfillment of the Requirements for the

Degree of

CIVIL ENGINEER

IN

THE GRADUATE SCHOOL

OF THE

UNIVERSITY OF ILLINOIS

1909

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UNIVERSITY OF ILLINOIS

THE GRADUATE SCHOOL

May 18, 1909

I HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

JOHN TRUESDALE STEWART

ENTITLED METHODS USED IN PRIMARY LEVEL AND TRIANGULATION WORK IN UNSETTLED AND BROKEN COUNTRY

BE ACCEPTED AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF Civil Engineer

John O. Brooks
In Charge of Major Work

John O. Brooks
Head of Department

Recommendation concurred in:

A. N. Talbot

Edward C. Schmidt

Committee on Final Examination

145219

Thesis

Describing the Methods Used in Primary (Grid) and Triangulation Work in Deserted and Desert Country.

Presented for the Degree of

B.S.

in

Civil Engineering

by

John T. Stewart

to the

University of Illinois

1909.

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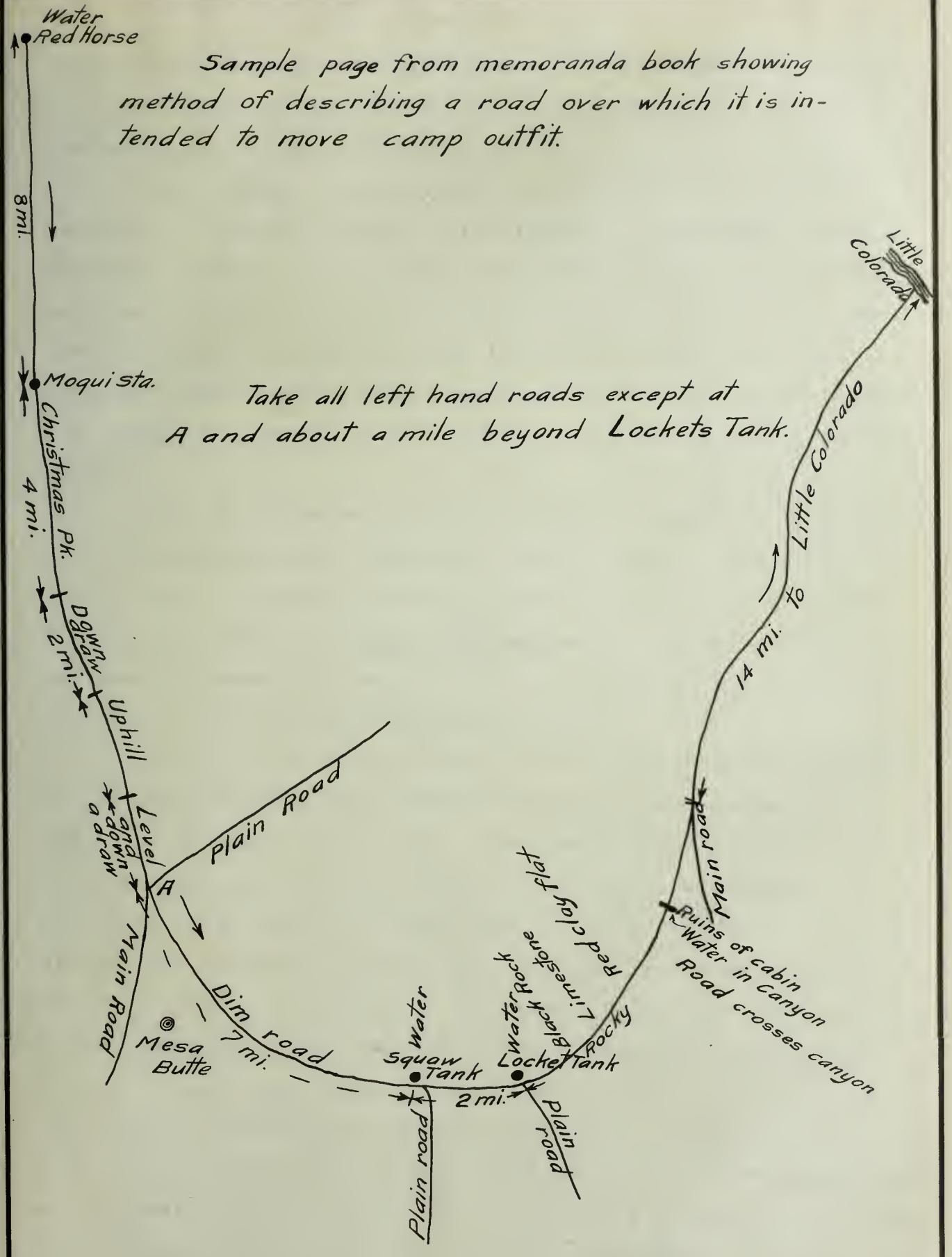
http://archive.org/details/methodsusedinpri00stew

Sample page from memoranda book showing method of describing a road over which it is intended to move camp outfit.



U. S.
GEOLOGICAL SURVEY
LEVEL BOOK

ANY PERSON

who finds this book will confer a favor by pasting the following addressed label on the outside and depositing it in the nearest post office.

Department of the Interior,
U. S. GEOLOGICAL SURVEY.
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To the Director of the

United States Geological Survey,

Washington, D. C.

6—921

office. [illegible] contained the following list of such supplies and directions for procuring.

1. Requisitions should be on form 9-125, using numbers and titles as below.

2. The articles generally needed by field parties engaged in different classes of work are indicated thus: Tr., for triangulation; L., for leveling.

3. The articles mentioned in the following list are supplied by the section of documents and stationery.

Tr., L.	9-006.	Purchase voucher, short.
Tr., L.	9-008.	Purchase voucher, long.
Tr., L.	9-010.	Pay voucher.
Tr., L.	9-012.	Pay roll-short.
Tr.	9-018.	Traveling expense voucher.
Tr., L.	9-019.	Subvoucher book.
Tr.	9-052.	Notification of shipment of property.
Tr., L.	9-054.	Inventory of property.
Tr.	9-125.	Requisition blanks.
Tr.	9-160.	Penalty [illegible]
Tr.	9-880.	Computation books.
Tr.	9-898.	Pocket notebook, detachable leaves.
Tr.	9-901.	Computation of geodetic distances.
Tr.	9-902.	Computation of geodetic coordinates.
L.	9-903.	Level book.
Tr.	9-920.	Monthly report, triangulation party.
Tr.	9-912.	Triangulation, field notebook.
L.	9-918.	Bench mark descriptions.
Tr., L.	1.84a.	Account book, 80 pages, index in front.
Tr., L.	Cards for forwarding mail.	
Tr.	Cards, chief clerk address.	
Tr., L.	Cards, postal.	
L.	Cards, weekly report, level party.	
Tr., L.	Envelopes, official, letter size.	
Tr.	Envelopes, official, letter size, return.	
Tr.	Envelopes, official, note size.	
Tr., L.	Envelopes, official, printed address.	
Tr., L.	Envelopes, official, blue, cloth lined.	
Tr.	Envelopes, official, manila, 9 1/2 by [illegible] inches.	
Tr., L.	Paper, pads, figuring, note size.	
Tr., L.	Paper, pads, official.	
Tr.	Paper, pads, ruled.	
Tr., L.	Pencils No. 5.	
Tr., L.	Penholders.	
Tr., L.	Pens assorted.	
L.	Rubber bands [illegible] 1/4 by 8 inches.	
Tr., L.	Rubber bands, assorted.	
Tr.	Rubber pencil erasers.	

4. The articles mentioned in the list below are furnished by the custodian of instruments.

Tr.	Compasses, prismatic.
Tr.	Chains (100, 66, or 33 feet).
Tr., L.	Cement, cans.

Tr.	Clamps, tie-o.
Tr.	Gradienters.
Tr.,L.	Inv. foundation and Target
L.	Levels, plumbing.
L.	Levels, Y.
L.	Leveling rods, New York.
L.	Paint, cans.
L.	Paint brushes.
L.	Pins, turning-point.
L.	Scribes, timber.
L.	Steel dies, sets, figures.
L.	Steel dies, reference letters.
L.	Tablets, aluminum.
Tr.	Tablets, meridian.
Tr.	Tablets, triangulation.
Tr.	Tapes, 300 foot, steel
L.	Tapes, 66 foot, metallic.
Tr.	Theodolites.

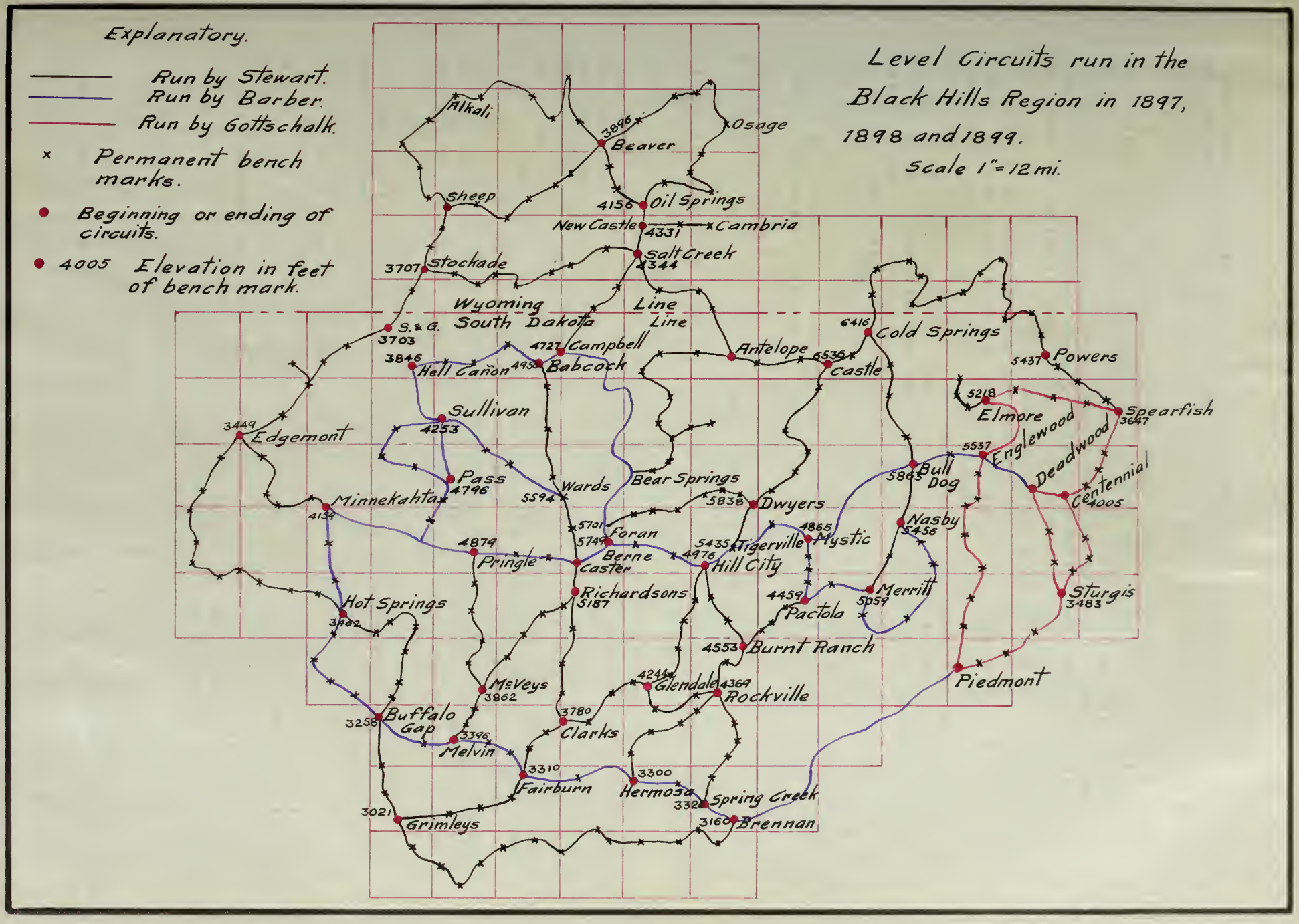
The object of the level work was to determine elevations for the control of topographic mapping. For the sake of uniformity in connecting the area surveyed with another, it was desirable to have the elevations of each based on a common datum, this was impractical for the reason that it would have required long and expensive lines of levels to connect the various areas, before mapwork could begin. Consequently, when an area was to be surveyed which was isolated from areas previously mapped, a datum based on sea level was established from the best information at hand. This datum was given a local name and certain reference letters. With this datum as a starting point level lines were run in circuits, each circuit beginning and closing on a bench mark which had previously been set. Where the topography of the land made it impractical to run a circuit the line was checked back over itself.

The instructions issued by the Bureau for this class of leveling have been revised from time to time as justified by field experience. The following issue of April 1904, necessary use of wye level practice, and many of the requirements now in the first issue of instructions were in use by the author before coming out as instructions.

Spirit leveling instructions.

1. A sufficient amount of accurate spirit leveling should be done to insure the placing of at least two standard bench marks in each township or equivalent area surveyed, except in forest-clad and mountain areas; and these bench marks shall be established, whenever practicable, near the township corners of the public-land surveys.

2. For each general locality of field work some centrally situated place should be chosen in which an elevation above sea level can be determined with appropriate accuracy from railroad or other surveys. In this place are to be established two control bench


Explanatory.
Run by Stewart.
Run by Barber.
Run by Gottschalk.
Permanent bench marks.
Beginning or ending of circuits.
4005 Elevation in feet of bench mark.
Level Circuits run in the Black Hills Region in 1897, 1898 and 1899.
Scale 1" = 12 mi.
Alkali
Osage
3896
Beaver
Sheep
4156
Oil Springs
New Castle
4331
Cambria
3707
Stockade
Salt Creek
4344
Wyoming
South Dakota
Line
Line
S. & G.
3703
4727
Campbell
3846
Hell Canon
4938
Babcock
Antelope
6536
Castle
6416
Cold Springs
5437
Powers
5218
Elmore
Spearfish
3647
Englewood
5537
Deadwood
Centennial
4005
Sullivan
4253
3449
Edgemont
Pass
4796
Minnekahta
4134
Wards
5594
Bear Springs
5838
Dwyers
5865
Bull Dog
5701
5749
Foran
Berne
Caster
4879
Pringle
5435
Tigerville
4865
Mystic
Nasby
5456
4976
Hill City
4459
Pactola
5059
Merritt
Richardsons
5187
Hot Springs
3402
4553
Burnt Ranch
Sturgis
3483
Piedmont
4244
Glendale
4369
Rockville
McVeys
3862
3780
Clarks
3258
Buffalo Gap
3396
Melvin
3310
Fairburn
3300
Hermosa
3321
Spring Creek
3021
Grimleys
3160
Brennan

earth marks, preferably those cemented in rock and masonry structures, to which will be referred all other bench marks in the neighborhood. A reference mark for each of these concrete ones will be established.

3. Standard bench marks established in the course of the work should be so located that, if the bench levels they will not be liable to injury or disturbance, yet shall be so prominently situated that they will be easy to find. They must consist of aluminum tablets fastened with Portland cement into solid rock or masonry structures, as the foundations of bridge piers, or of the standard bronze capped iron posts, which should be so set in the ground as to project about 1 foot above the ground. Where standard bench marks should be set about 1 mile apart. The intersection of the cross lines is the bench mark.

4. Primary level lines, wherever practicable, should be run in circuits which will check back upon themselves or other lines. Where such lines are run, they should be checked preferably by re-running in the opposite direction.

5. Levelmen and rodmen must use separate notes and no comparisons should be made until the record is complete. If the results differ more than .001, each must read the rod before recording anything but results. All notes must be recorded directly in the note book. Separate pieces of paper for figuring or temporary records must not under any circumstances be used. For a given day's notes must be at least two lines lower down page than levelman's and they should not turn over leaf at same time.

6. Work or setting bench marks must not be carried on during high winds or when the air is boiling badly. During very hot weather an effort should be made to get to work early and to remain out late, rather than to work during middy.

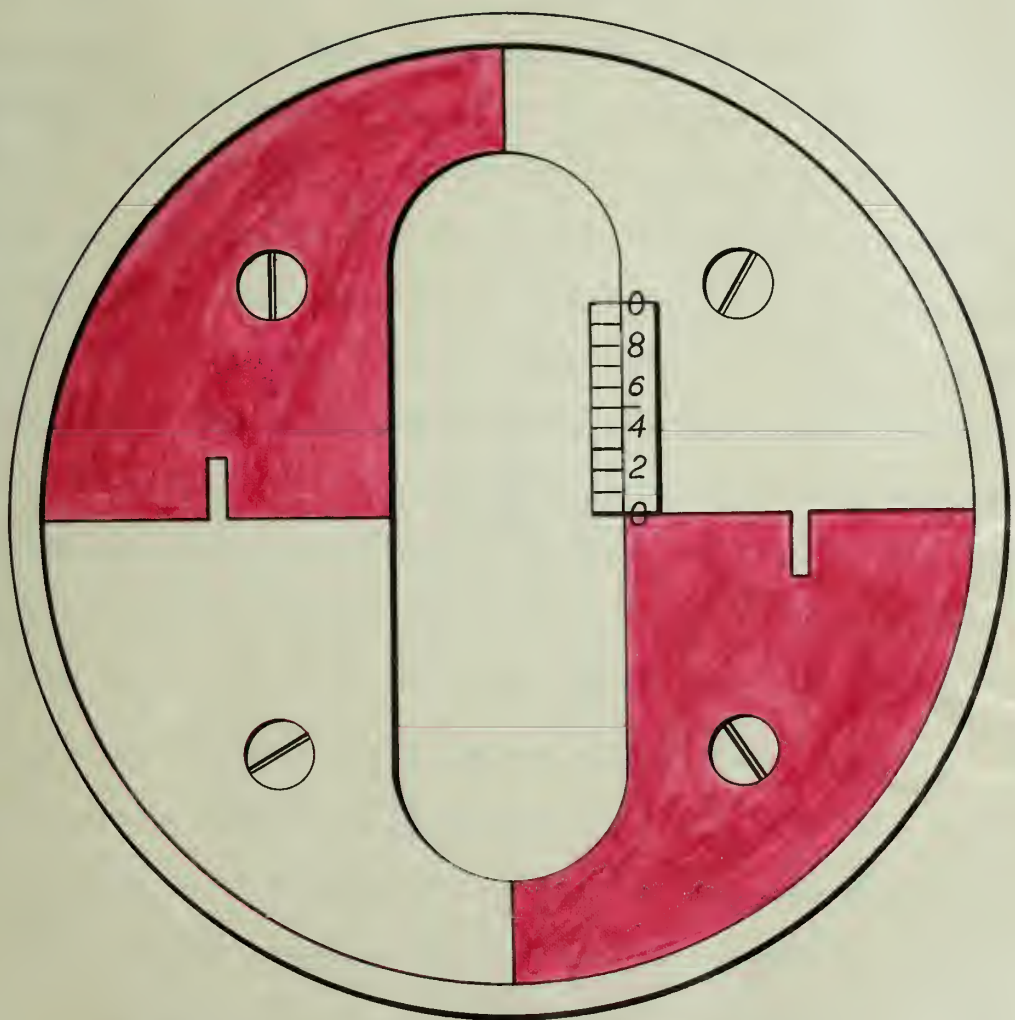
7. Rods and back sights should be of equal length, and no sight over 300 feet should be taken, except under unavoidable circumstances, as in crossing rivers, etc. Under such conditions, requiring established turning points on both sides of the stream or valley and without changing the adjustment of the level, be sure to set up on each bank about 50 feet from the turning point, taking first a back sight to rear and foresight to distant turning point, then cross stream or valley and take a backsight to distant and foresight to rear turning point, thus determining the elevation of each turning point by short backsight and long foresight and avoiding long backsight and short foresight. The mean of these determinations will be the true elevation.

8. If it is impracticable to take equal rear and fore sights as soon as the obstacle is passed the engineer must make such adjustments as will insure correct adjustment of the level, which must not be altered until the sights have been obtained.

9. Distances along a railroad can be obtained by counting rails, and pacing when rails of different lengths from the ordinary 30-foot rail are encountered. At other times stadia or pacing may be used according to the quality of the work. The distances in miles of both fore and back sights must be recorded in both note-book s in the proper columns. The pace of the average man is about 2,000 to the mile; thus, if each time the right or the left foot strikes the ground is counted, it will approximate to 1,000 to a mile.

10. The tripod pinching screws must be loosened when the instrument is set, and thereafter only lightly and it is placed. Always level the instrument carefully before setting the target, after setting it and before giving the signal "all right" during

Vistance in miles.



Special Target
for
New York Level Rod.

Designed by John T. Stewart.

New Style New York Leveling Rod.

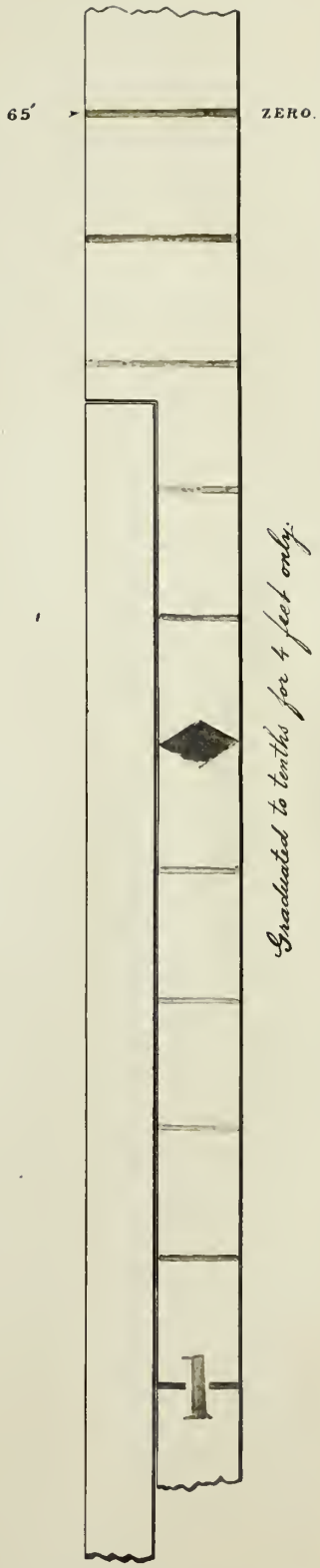
U.S.G.S.

Front of rod figured from 2 to 65 only.

Left side of rod figured from 65 to 120 only.

Designed by John T. Stewart.

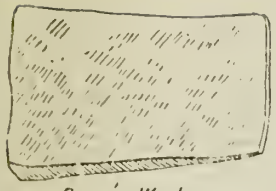
Full Size



Right side of rod.

USGS
LBM

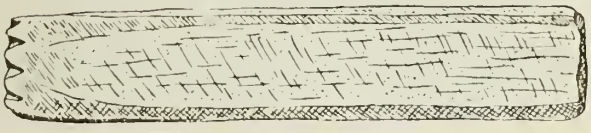
BM



Brass Wedge.

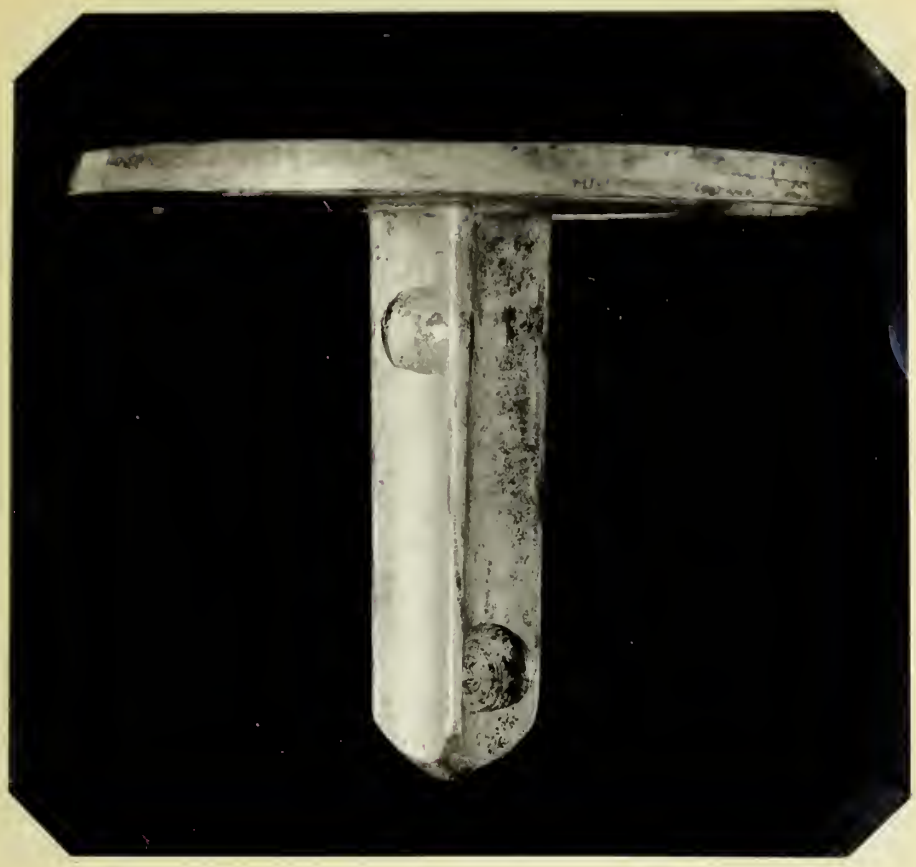
Copper Bolt.

Steel Die.

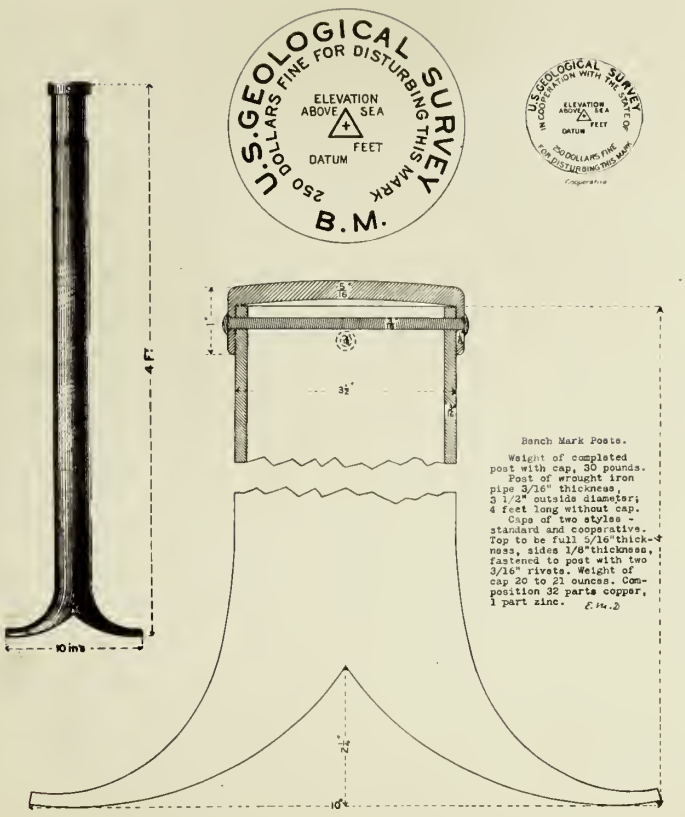


U.S.C.
T7
.M.8

U.S.GEOLOGICAL SURVEY
FINE FOR DISTURBING THIS MARK
250 DOLLARS
ELEVATION ABOVE SFA
DATUM
FEET
B.M.



U.S.GEOLOGICAL SURVEY
FINE FOR DISTURBING THIS MARK
250 DOLLARS
ELEVATION ABOVE SEA
4543 FEET
DATUM DW
B.M.


U.S. GEOLOGICAL SURVEY
250 DOLLARS FINE FOR DISTURBING THIS MARK
ELEVATION ABOVE SEA
FEET
DATUM
B.M.
U.S. GEOLOGICAL SURVEY
IN COOPERATION WITH THE STATE OF
ELEVATION ABOVE SEA
FEET
DATUM
250 DOLLARS FINE FOR DISTURBING THIS MARK
Cooperative
4 Ft.
10 in's
3½"
2½"
10"
Bench Mark Posts.
Weight of completed post with cap, 30 pounds.
Post of wrought iron pipe 3/16" thickness, 3 1/2" outside diameter; 4 feet long without cap.
Caps of two styles - standard and cooperative. Top to be full 5/16" thickness, sides 1/8" thickness, fastened to post with two 3/16" rivets. Weight of cap 20 to 21 ounces. Composition 32 parts copper, 1 part zinc.
E.14.2

No. 5

DEPARTMENT OF THE INTERIOR,

UNITED STATES GEOLOGICAL SURVEY.

SPIRIT-LEVEL OBSERVATIONS.

State, Wyoming

Atlas Sheet, Newcastle, Sundance

DATUM:

Deadwood

Elevation, 4543.472 *feet.*

John T. Stewart
Chief of Party.

John T. Stewart
Levelman.

E. R. Bartlett
Rodman.

These notes kept by John T. Stewart

Sept. 21 – Oct 22, 1900

6—921

2 Date, Sept. 21 , 1900

Dist B.S.	Dist F.S.	Back Sight	H.I.	Fore Sight	Elevation	

Antelope Spring Circuit

Circuit from Antelope Spring or Beaver Creek Wyo. thence down Beaver West to Newcastle, thence East [over 3 to Campbell's Ranch at intersection of D.W. Thompson's Ranch, in S. Dak. West to Creek to Sweet and Davis Sawmill thence mi of same road] to LAK Ranch, thence S.E. Buck Springs and Gillett Canyons in S. Dak.

210		2.931	6484.963		6480.032	B.M. D.W. Thompson's Ranch 0.7 mi south of
140	210	11.697	6491.850	2.810	6480.153	Iron Post Marked 6480 [Unadjusted]
90	140	11.883	6502.902	0.831	6491.019	
100	90	11.827	6513.517	1.212	6501.690	
100	100	8.337	6521.035	0.819	6512.698	
75	100	11.950	6532.039	0.946	6520.089	
100	75	10.775	6539.737	3.077	6528.962	
190	100	9044	6547.863	0.918	6538.819	
95	190	0.748	6537.635	10.476	6536.887	
200	95	2.130	6529.716	10.049	6527.586	
200	200	2.285	6520.512	11.489	6518.287	
125	200	6.221	6514.752	11.981	6508.531	
125	125	9.321	6522.567	1.506	6513.246	
150	125	8.803	6530.437	0.933	6521.634	
250	150	10.418	6537.389	3.466	6526.971	
95	250	0.871	6531.262	6.998	6530.391	Summit
	95	119.241		11.157	6520.105	
	2245			79.168	40.073	

Weather Cloudy and windy.
Run 2.1 mi.
Set 1 P.B.M.
Set 1 T.B.M.

Week ending Sept 21
worked 3¾ da.
Run - 12.2 - mi.
Set - 2 - P.B.M.
Set - 4 - T.B.M.
2 - Elev.

12

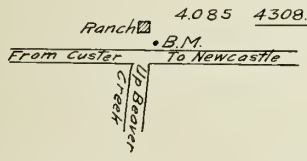
Date, Oct. 5 , 1900

Dist. B.S.	Dist. F.S.	Back Sight	H.I.	Fore Sight	Elevation	Sta.
200		2.233	4341.803		4339.570	
200	200	0.985	4330.898	11.890	4329.913	
300	200	2.418	4322.063	11.253	4319.645	
				5.038	4317.025	B.M.
200	300	0.824	4313.367	9.520	4312.543	
250	200	2.075	4305.507	9.935	4303.432	
85	250	1.040	4296.581	9.966	4295.541	
300	85	1.146	4287.727	10.000	4286.581	
				18.5	4269.2	
	300			9.292	4278.435	
		≀	≀	≀	≀	
75		10.915	4307.567		4296.652	
30	75	5.773	4312.090	1.250	4306.317	
	30			4.085	4308.005	B.M.

4317.025 Levelman
4317.033 Rodman
4317.029 Mean
Antelope Spring 24.3 mi. from
Newcastle 4.1 mi. E. of. 30 ft. N of road.
Wire nail in root of Pine 18in. diam.

Salt Creek West from L A K Ranch.

4308.005 Levelman
4308.010 Rodman
4308.007 Mean
Antelope Spring 26.3 mi. from.
L A K Ranch 75 ft. E. of. S. side of road.
Iron Post Marked 4308



250		8.372	4316.377		4308.005	B.M.
	250	≀	≀	0.747	4315.630	
				≀	≀	

21 Date, Oct. 8, , 1900

Dist B.S.	Dist. F.S.	Back Sight	H.I.	Fore Sight	Elevation.	Sta
160		11.219	4703.007		4691.788	
200	160	8.628	4710.146	1.489	4701.518	
150	200	10.814	4719.770	1.190	4708.956	
40	150	10.300	4729.124	0.946	4718.824	
	40			1.890	4727.234 B.M.	

Check B.M.
4727.234 Levelman.
4727.232 Rodman
4727.233 Mean
Antelope Spring 34.4 mi. from.
Campbell's Ranch at intersection of
Buck Spring and Gillett Canyon in
S. Dak.
Iron Post Marked 4727

[4727.233 + 0.178] = 4727.411 Closing Elevation plus Adjustment.
Correction of starting B.M. at
Thompson's Ranch.

4727.367 Original Elev. of B.M. (Adjusted)

Error = 0.044 high
Length of circuit 33.7 mi.

23 Date, Oct. 17, 1900

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Dist. B. S.	Dist. F. S.	Back Sight	H. I.	Fore Sight	Elevation	
150		5.062	5866.655		5861.593	
150	150	3.966	5867.740	2.881	5863.774	
				0.912	5866.828	Rock check point
200	150	9.153	5874.799	2.094	5865.646 T.P.	See P.B.M. on Page 25
	200	≀	≀	2.313	5872.486	
				≀	≀	
110	175	5.600	5979.637	0.962	5974.037	
	110			2.527	5977.110	

Weather Clear
Run 3.5 mi.
Set-1-T.B.

Oct. 18-1908.

100		2.622	5868.268		5865.646 T.P.	on Page 23
	100			1.212	5867.056 B.M.	5867.056 Elev.

Cold springs 12.9 mi from. Flemings Ranch
N.E. of N of road. Rock 3x3 ft. and 2 ft. high.
Bronze Tablet Marked 5867
W.T. 100 ft. N.E. Pine 18" dia
W.T. 120 ft NW. Pine 18" dia.

◎ W.T. ◎ W.T.
⊙ B.M.
Up Lost Canyon →

Check

	1.211	5868.267		5867.056 B.M.	
			1.434	5866.833 Rock.	
175	8.541	5985.651		5977.110	
175			3.352	5982.299	
	≀	≀	≀	≀	

49 Date, Oct. 19, , 1900

6—921

Dist. B. S.	Dist. F. S.	Back Sight.	H I.	Fore Sight.	Elevation.	Sta.
		Snow Storm				
		Oct. 20, 1900				
		Snow Storm				
		Oct. 21, 1900				
45		11.088	6188.193		6177.105	
75	45	11.213	6198.147	1.259	6186.934	
	75	≀	≀	0.904	6197.243	
150	150	2.072	5933.861	≀	≀	
150	150	1.660	5927.407	8.114	5925.747	
	150			8.688	5918.719	

Continued Page 1 Book 6

1 Date, Oct. 24, , 1900

Dist B.S.	Dist F.S.	Back Sight	H.I.	Fore Sight	Elevation	Sta
		Continued from Page 49 - Books				
105		2.514	5921.233		5918.719	
200	105	2.427	5914.939	8.721	5912.512	
	200	≀	5906.430	11.063	5903.876	
			≀	≀	≀	
		Oct 31, 1903				
50		11.499	6431.759		6420.260	
40	50	11.246	6441.844	1.161	6430.598	
40	30	10.636	6451.454	1.026	6440.818	
40	50	10.891	6461.579	0.766	6450.688	
35	40	11.530	6472.355	0.754	6460825	
35	35	12.055	6483.613	0.797	6471.558	
35	35	11.553	6494.198	0.968	6482.645	
40	35	11.541	6505.013	0.726	6493.472	
	40	≀	≀	0.760	6504.253	
				≀	≀	

Month ending Oct. 31, 1903
Run - 47.0 - mi.
Set 13 - P.B.M.
Set 24 - T.B.M.
5 - Elev.
Worked 18¾ days.
(Closed 1 Circuit.)
Error 0.044 ft.
Length 33.7 mi.)
Field expenses $36.47
Salaries 155.00
191.47

BOOK No. 1

DEPARTMENT OF THE INTERIOR.

UNITED STATES GEOLOGICAL SURVEY.

BENCH-MARK DESCRIPTIONS.

SPIRIT-LEVEL ELEVATIONS.

State South Dakota

Atlas Sheets Deadwood, Custer, Harney Peak

Datum Deadwood *Datum Elevation* 4,543.472

Datum Letters D.W. John T. Stewart
Levelman.

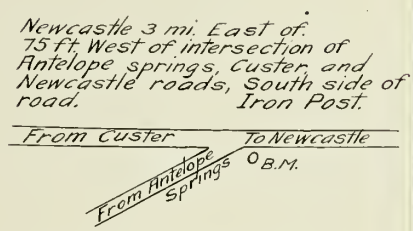
John T. Stewart,
Chief of Party.

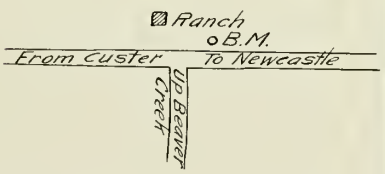
Adjustment by

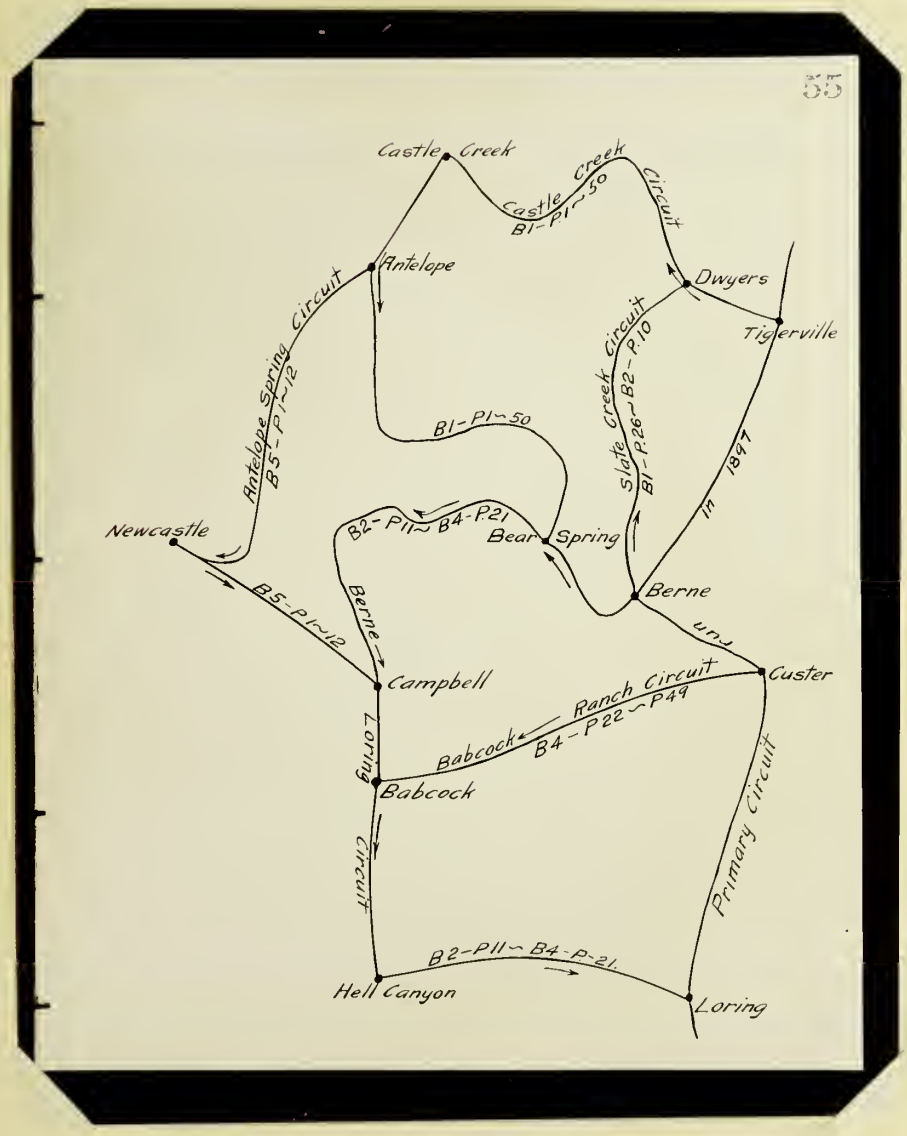
Date July 1 to November 10, 1900 6—1060

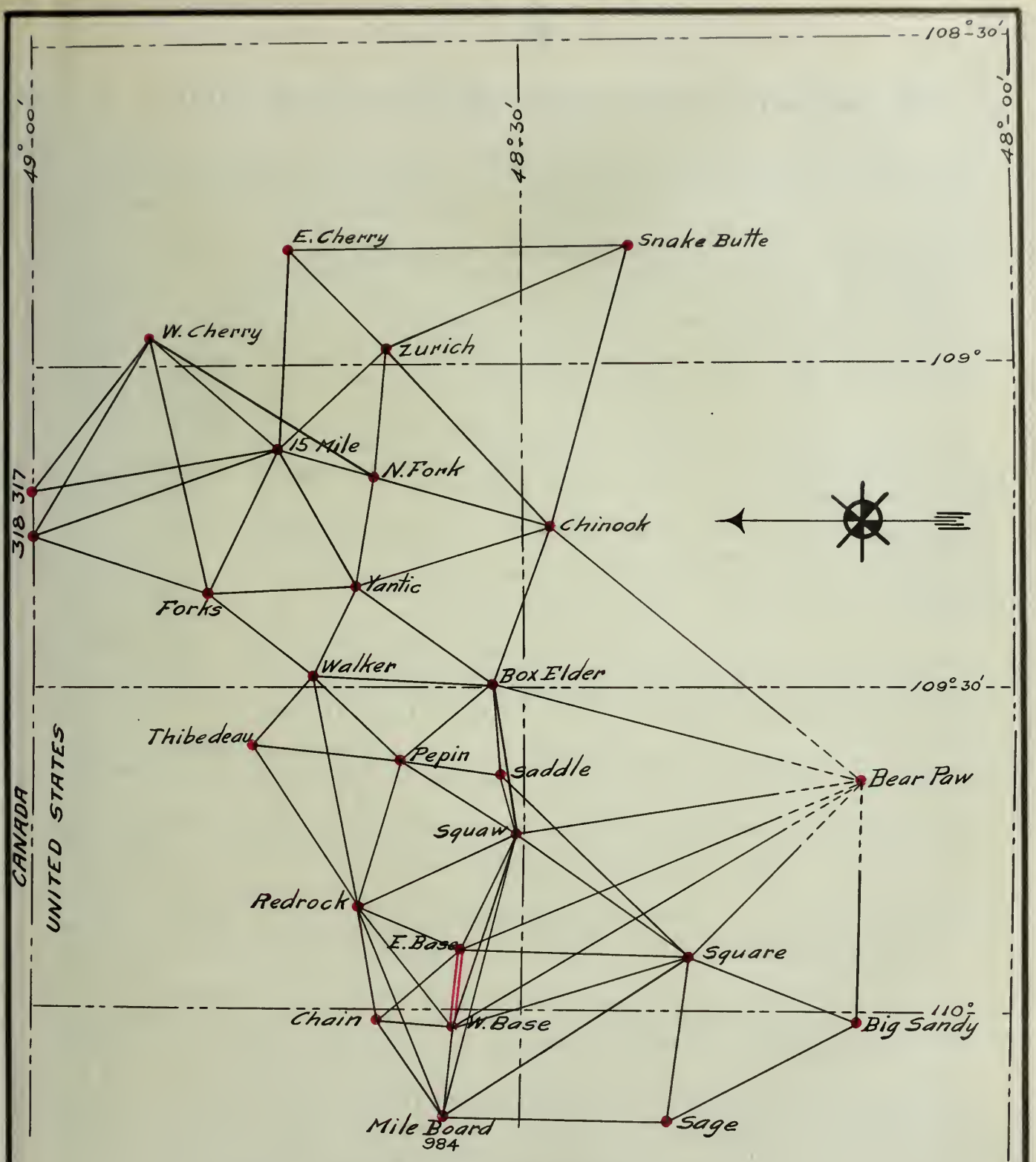
Date Oct. 5–6 1900 Line from 3 miles East of Newcastle to 1.9 mi. East of LAK ranch.

Level Notes Book	Page	Miles From Antelope Spring	Marked D. W.	Elevation	Adjusted Elevation	Description
5	10	23.2	4344	4344.202		Newcastle 3 mi. East of. 75 ft. West of intersection of Antelope springs, Custer and Newcastle roads, South side of road. Iron Post.
5	12	24.3	4317	4317.029		Newcastle 4.1 mi. East of. 30 ft. N. of road. Wire nail in root of pine 18 in. diam.
5	12			4269.2		Salt Creek West of LAK Ranch surface of Water
5	12	26.3	4308	4308.007		LAK Ranch 75 ft. East of. South side of road Iron Post
5	14	28.2	4397	4397.421		LAK Ranch 1.9 mi. E. of. Top of stake driven level with surface of ground at fence post. 200 ft. south of fence corner on west side of road.






Castle Creek
Castle Creek Circuit
B1-P1~50
Antelope
Dwyers
Tigerville
Antelope Spring Circuit
B5-P1~12
B1-P1~50
Slate Creek Circuit
B1-P26~B2-P10
In 1897
Newcastle
B2-P11~B4-P21
Bear Spring
Berne
B5-P1~12
Berne
Campbell
Custer
Ranch Circuit
B4-P22~P49
Loring
Babcock
Babcock
Circuit
Primary Circuit
B2-P11~B4-P21
Hell Canyon
Loring



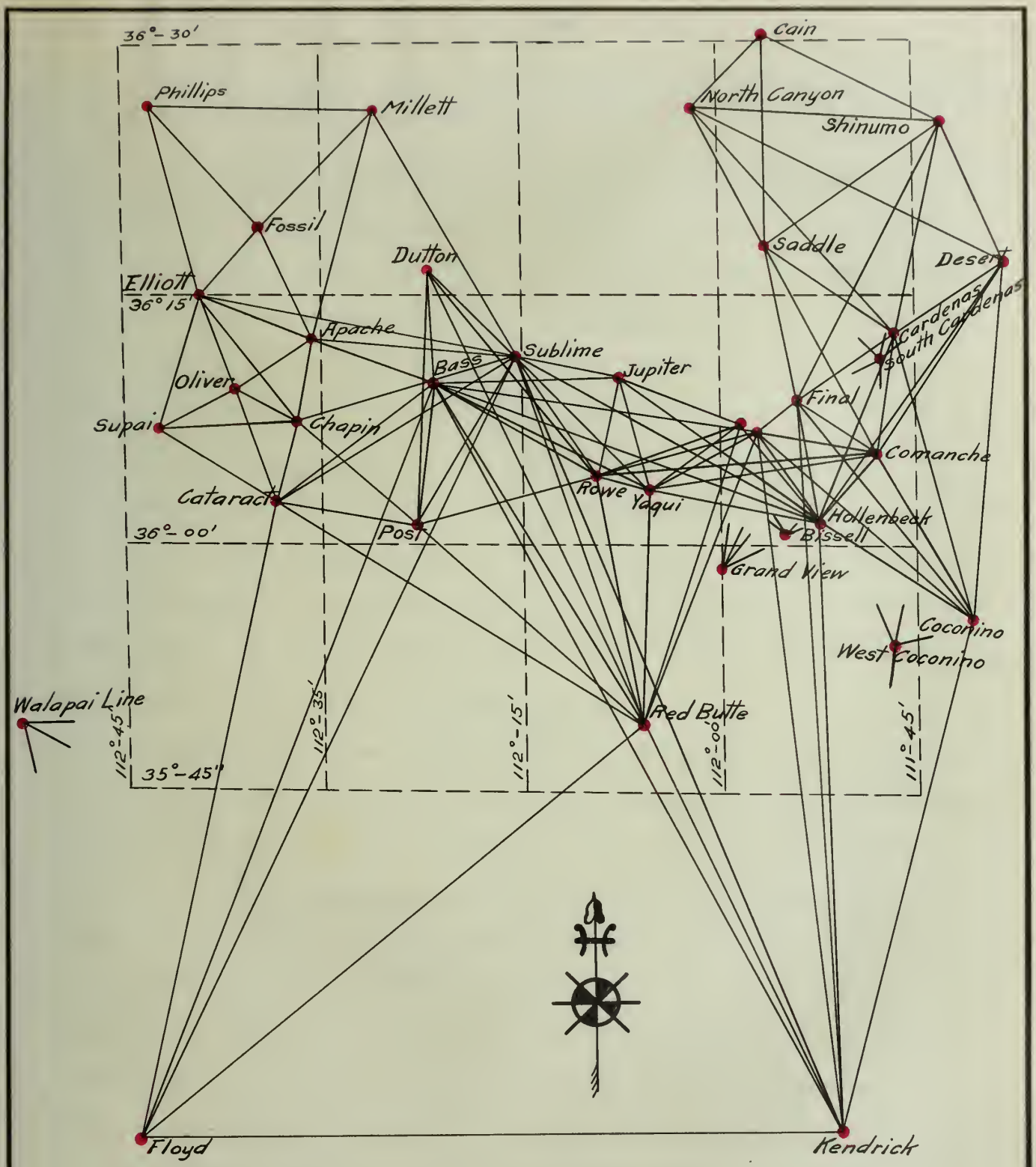
Triangulation System in the Vicinity of Havre, Montana

by

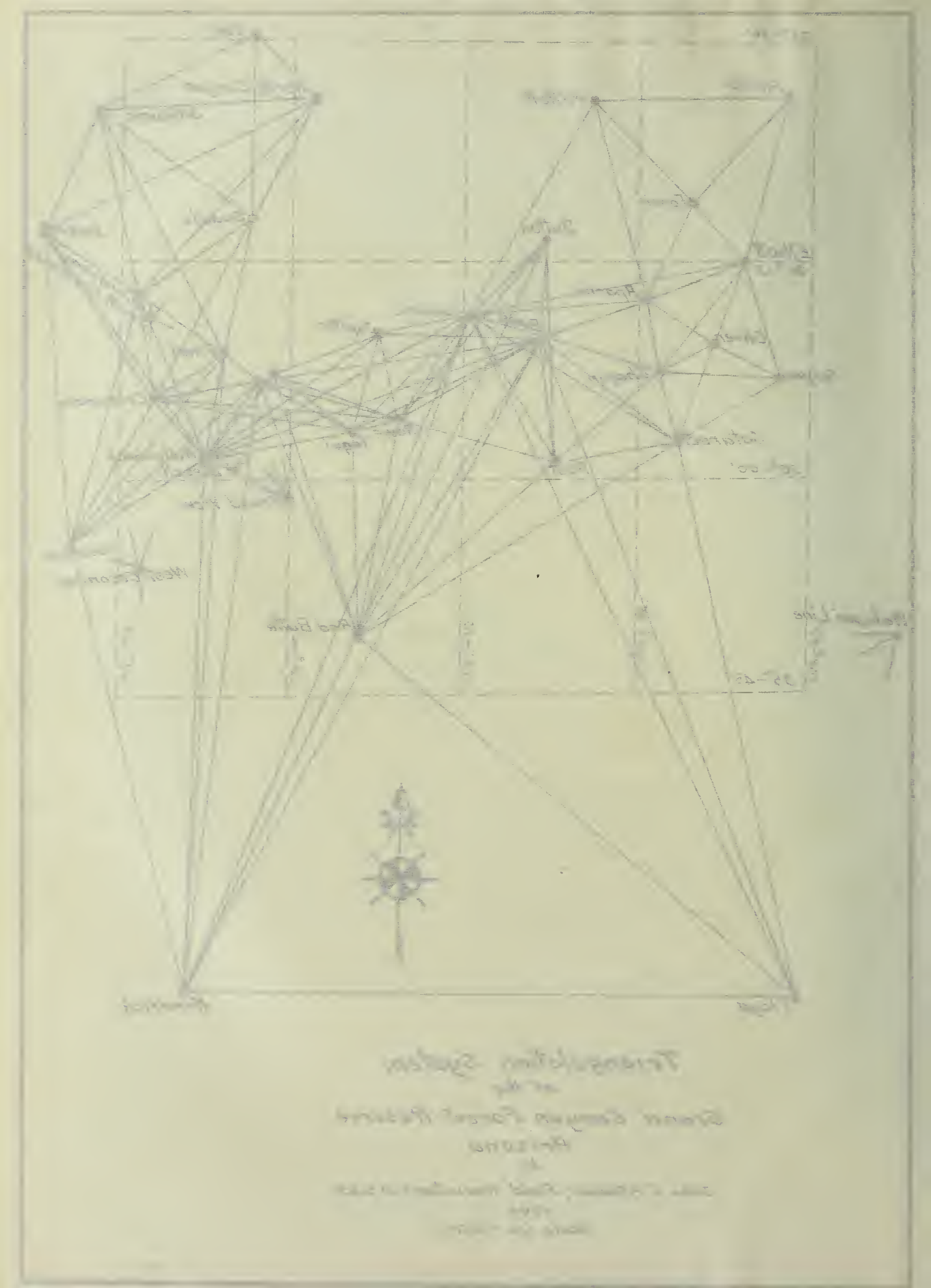
John T. Stewart, Field Asst. U.S.G.S.

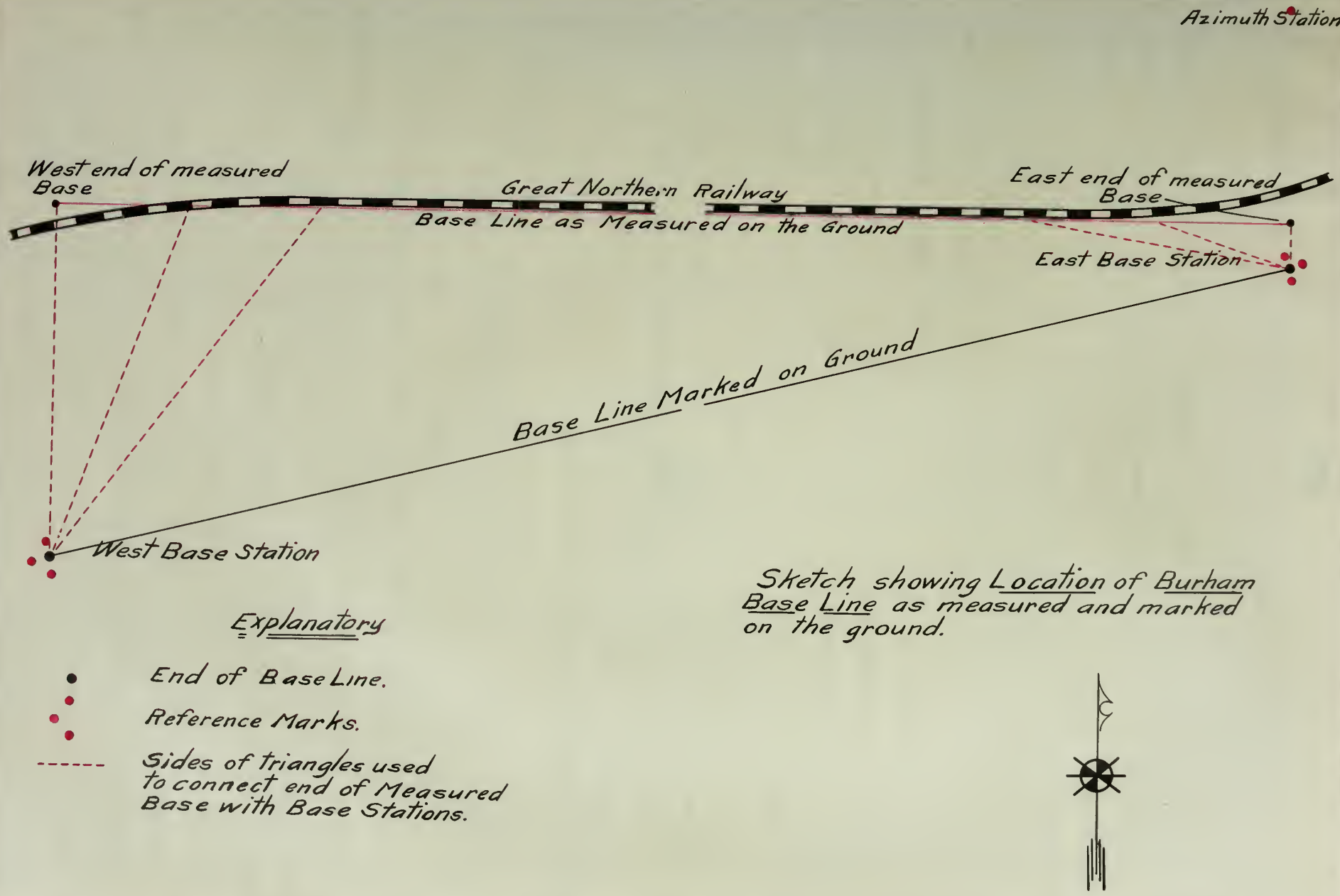
1902

Scale 1 in = 10 mi.



Triangulation System
of the
Grand Canyon Forest Reserve
Arizona
by
John T. Stewart, Field Assistant, U.S.G.S.
1903
Scale 1 in. = 10 mi.




Azimuth Station
West end of measured Base
Great Northern Railway
Base Line as Measured on the Ground
East end of measured Base
East Base Station
Base Line Marked on Ground
West Base Station

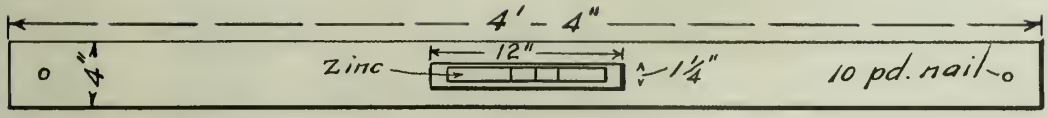
Sketch showing Location of Burham Base Line as measured and marked on the ground.

Explanatory

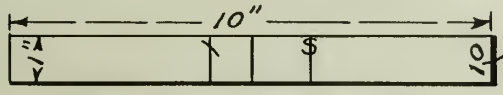
End of Base Line.

Reference Marks.

Sides of triangles used to connect end of Measured Base with Base Stations.

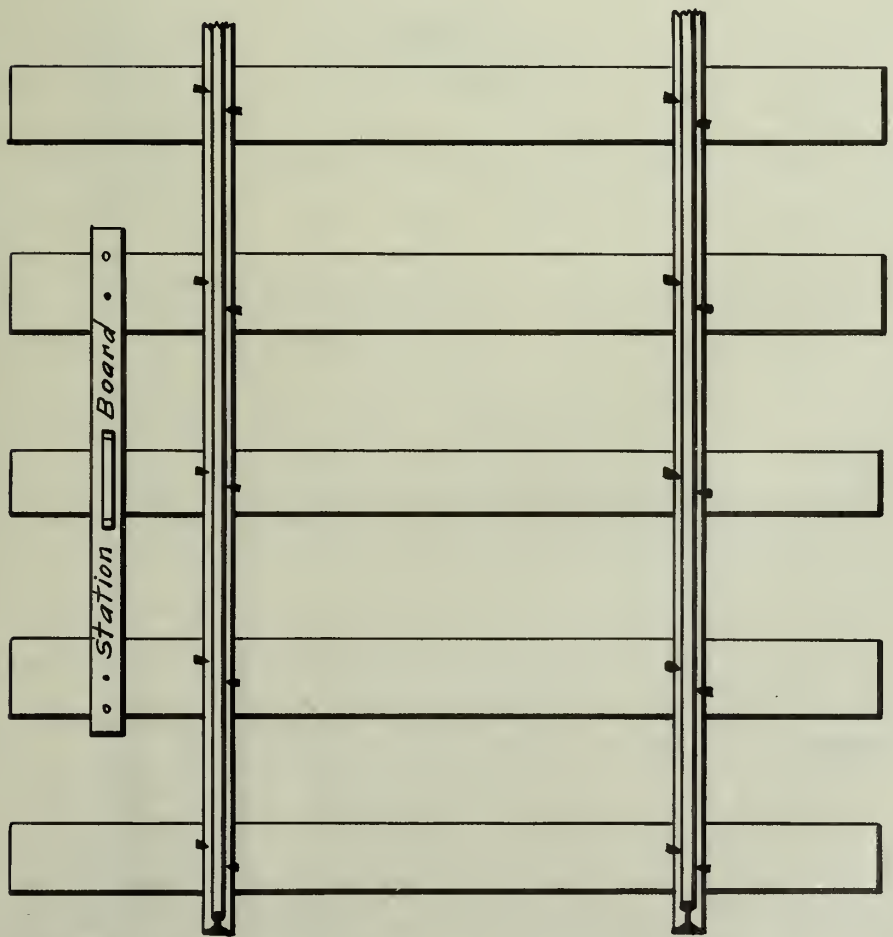


Details of Base Line Station Board.

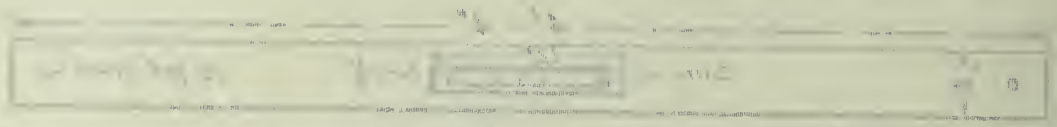


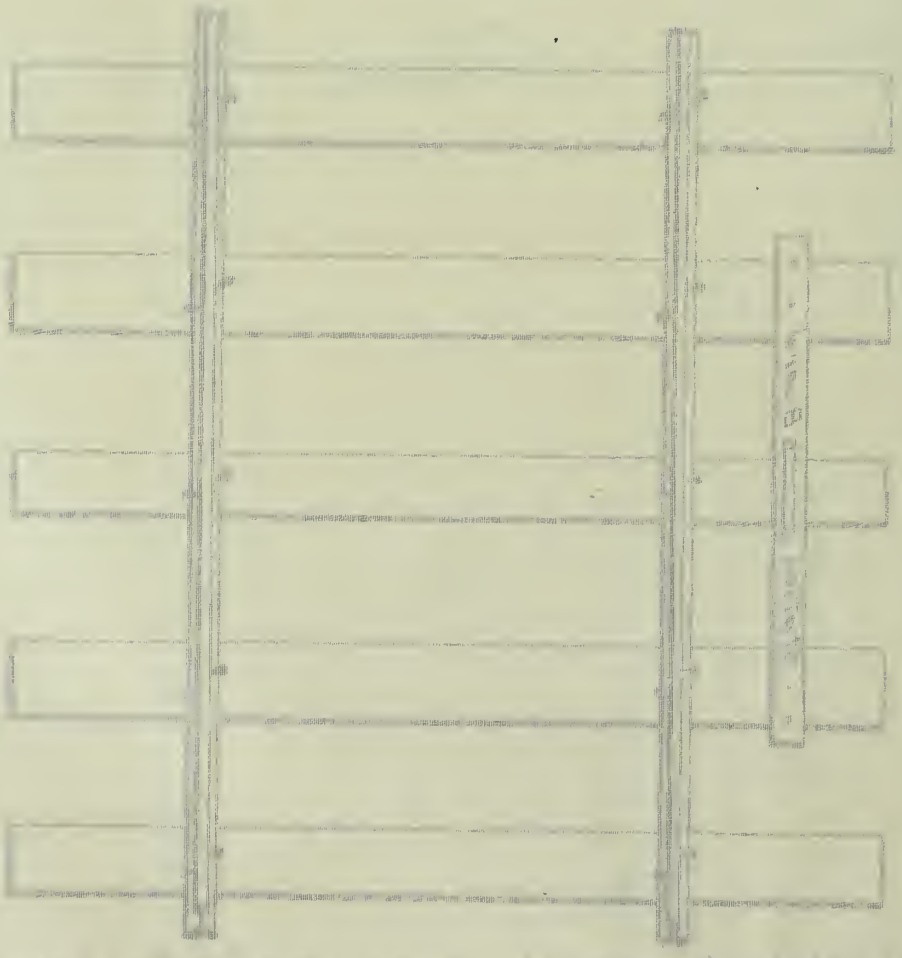
Zinc Station Plate.

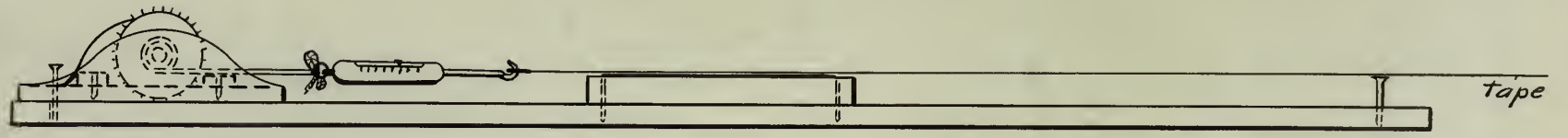
| 1st. measurement.
1 2nd. measurement.
$ 3rd. measurement.



Sketch showing the arrangement of a Base Line Station on the railroad track.

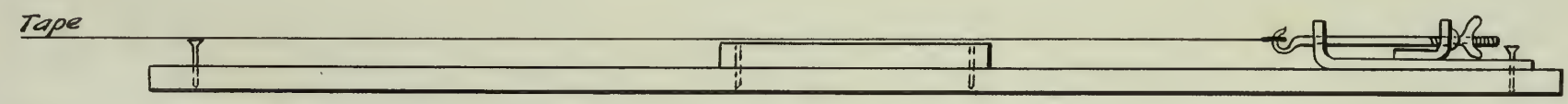






Vertical projection of tape stretcher and front station board while stretching tape.

Horizontal projection of tape stretcher and front station baard while stretching tape.



Vertical projection of tape clamp and rear station board while stretching tape.

53

Station Occupied 2nd Base Measurement — Observed

Date, July 27 1902 — Recorded

Stations Sighted — Microm. A — Microm. B — Means — Assgd

Station	Tension in Pounds	Thermometer A	Thermometer B	Temperature Correction	Length of Section	Remarks
0~1	20	63.5	64.0	Av. temp. 62.3°	0.135 feet longer than 1st measurement.	
2	"	63.5	64.0	62°+62.3°=+0.3°		
3	"	63.0	63.5	0.3×0.021=0.006ft.	Measured length 3000.000	
4	"	62.5	62.0			
5	"	62.0	62.0			
6	"	61.5	61.5			
7	"	61.5	62.0			
8	"	62.0	62.0			
9	"	61.0	61.0			
10	20	62.0	62.0			
3000		62.25	62.40			
10~11	20	62.5	62.5			
12		61.5	61.5			
13		61.0	61.0			

Time of beginning 10.05 P.M. July 27 - 1902. Thermometers, were laid on the ties along the tape 20ft from the ends. A at rear end. B at front end.

Time of quitting 4.30 A.M. July 28.

49

Station Occupied, Rowe

Date, September 10. 1903

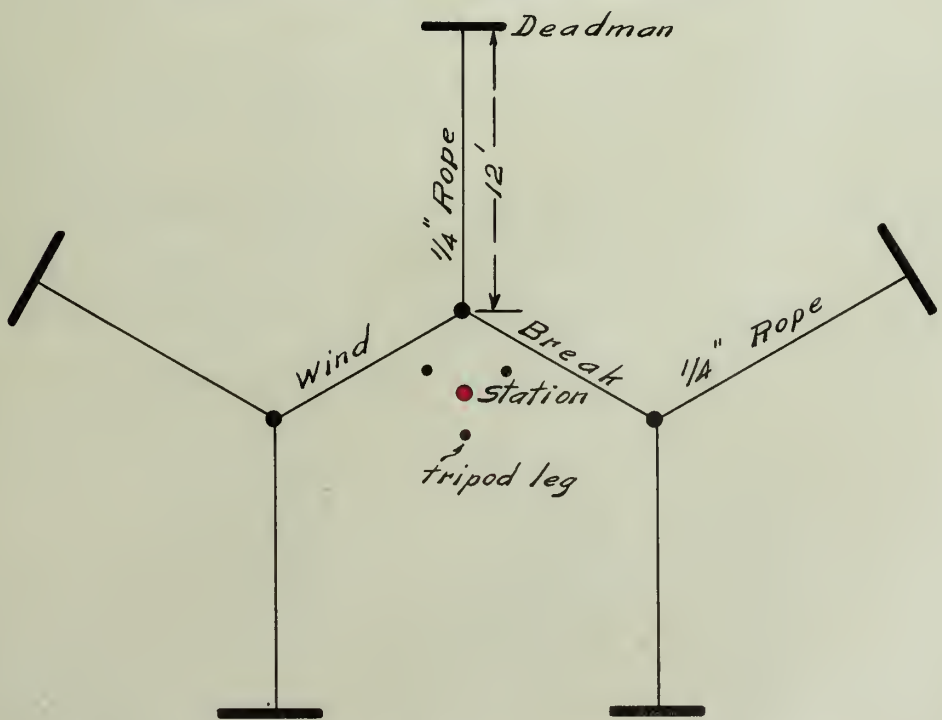
Observer, John T. Stewart.

Recorder, Norman Oliver.

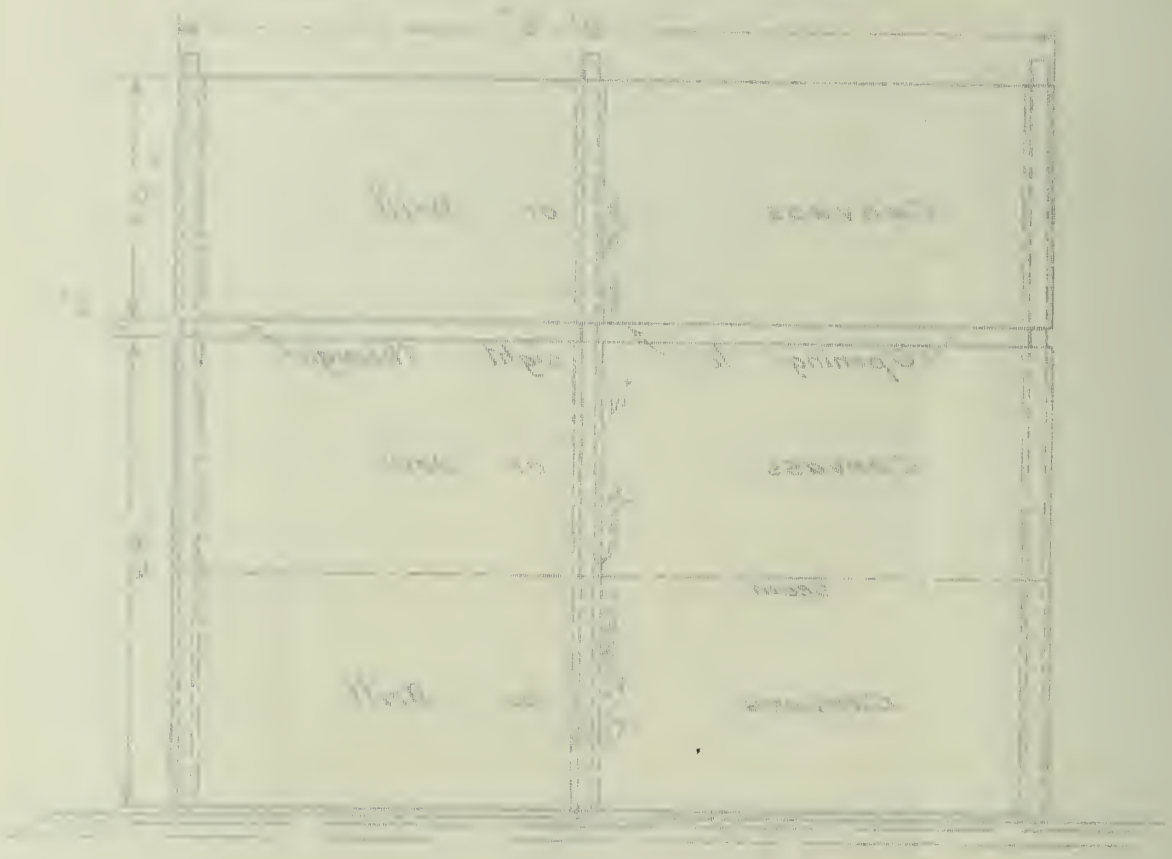
Stations Sighted	Time	Microm. A.	Microm. B	Mean.
		div.	div.	
Star 4	20 35	222 46 00	42 46 00	222 46 00
Mark		315 23 05	185 22 29	315 23 04
Mark		135 23 05	315 23 0	135 23 05
Star 4	29 19	42 43 20	222 43 08	42 43 28
4	26 45	80 38 20	260 38 10	80 38 30
		173 20 08	33 20 04	173 20 12
		353 20 12	173 20 00	353 20 12
4	59 21	260 31 17	80 31 13	260 31 30
5	05 04	295 35 12	115 35 09	295 35 21
		28 25 19	208 25 09	28 25 28
		208 25 21	28 25 24	208 25 45
5	14 09	115 33 01	295 33 03	115 33 04

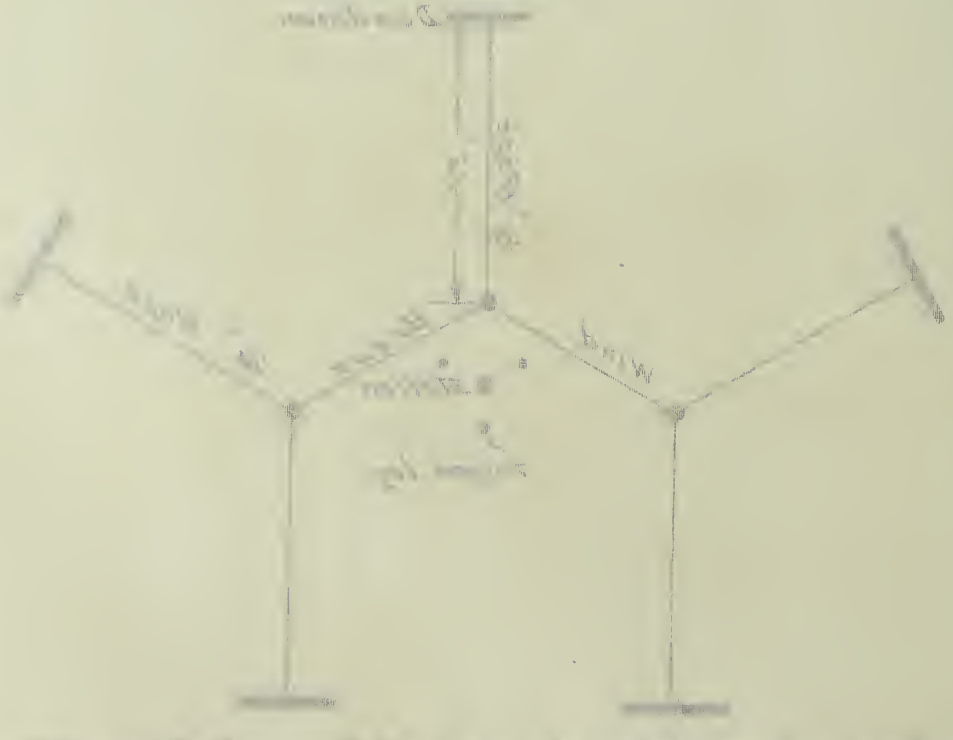
Angle			LEVEL			
			Direct		Reversed	
			E.	W.	E.	W.
			08	14	08	14
92	37	04				
92	39	37				
			11	11	11	11
			11	10	12	10
92	41	42				
92	48	42				
			11	11	12	11
			12	11	12	11
92	50	07				
92	52	41				
			12	11	12	11

Details and Dimensions of Wind Break.



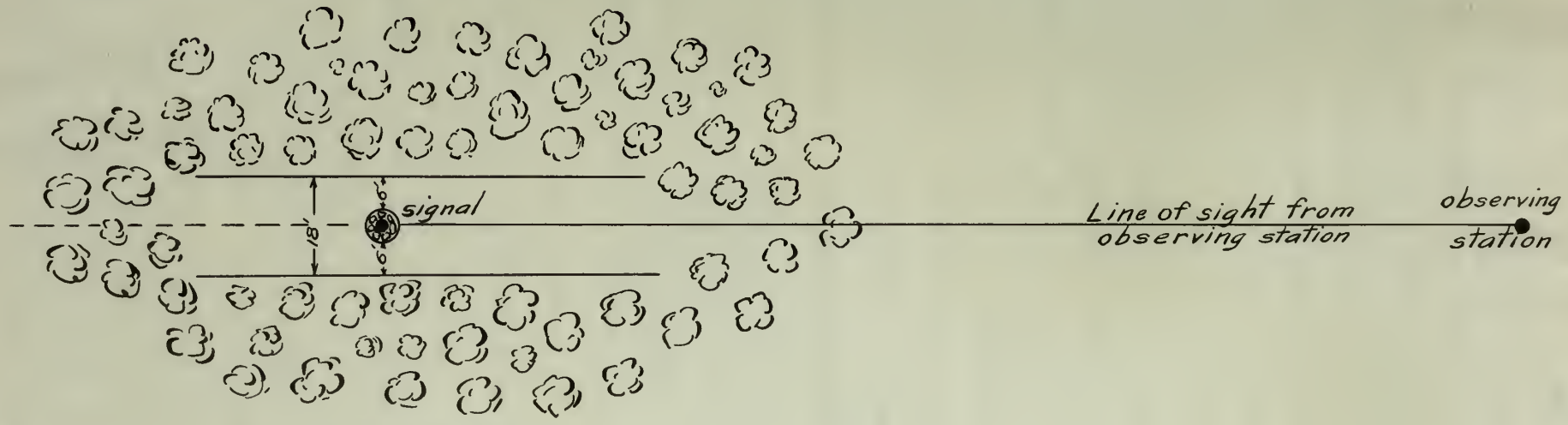
Position of wind break and station at time of making observations.





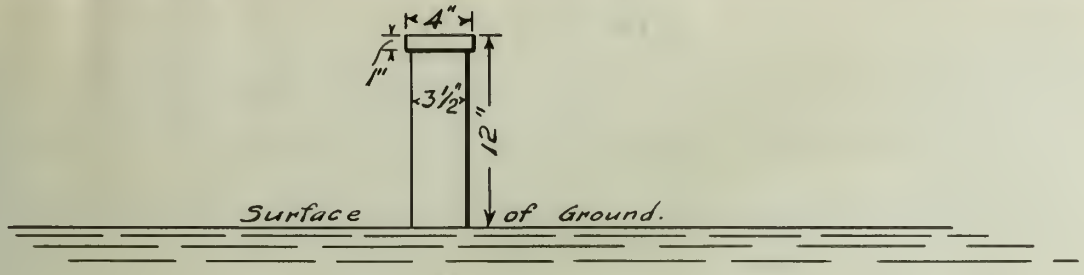
Reconnoitering for Transmission crossing from a head land on the south side of the Grand Canyon.

Sketch showing timber which should be cut to render an opaque signal visible on an oval topped hill.

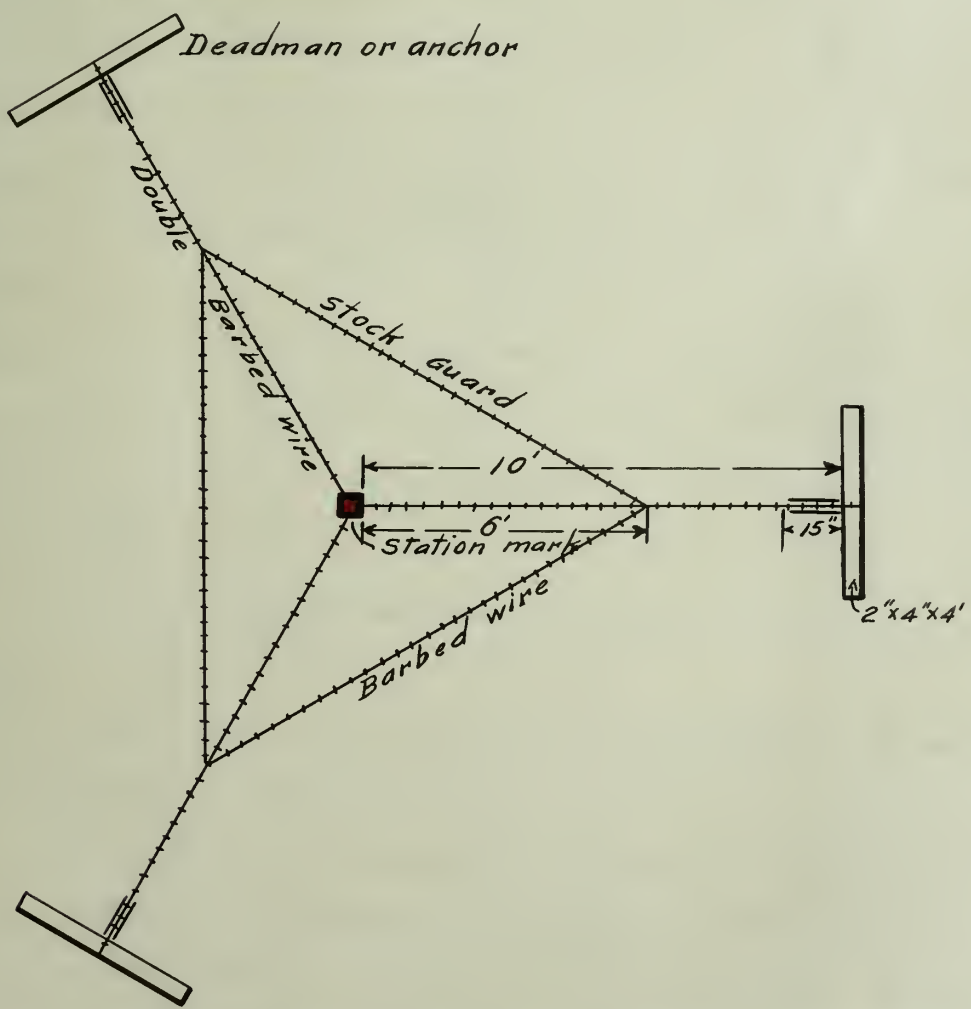


Horizontal Projection

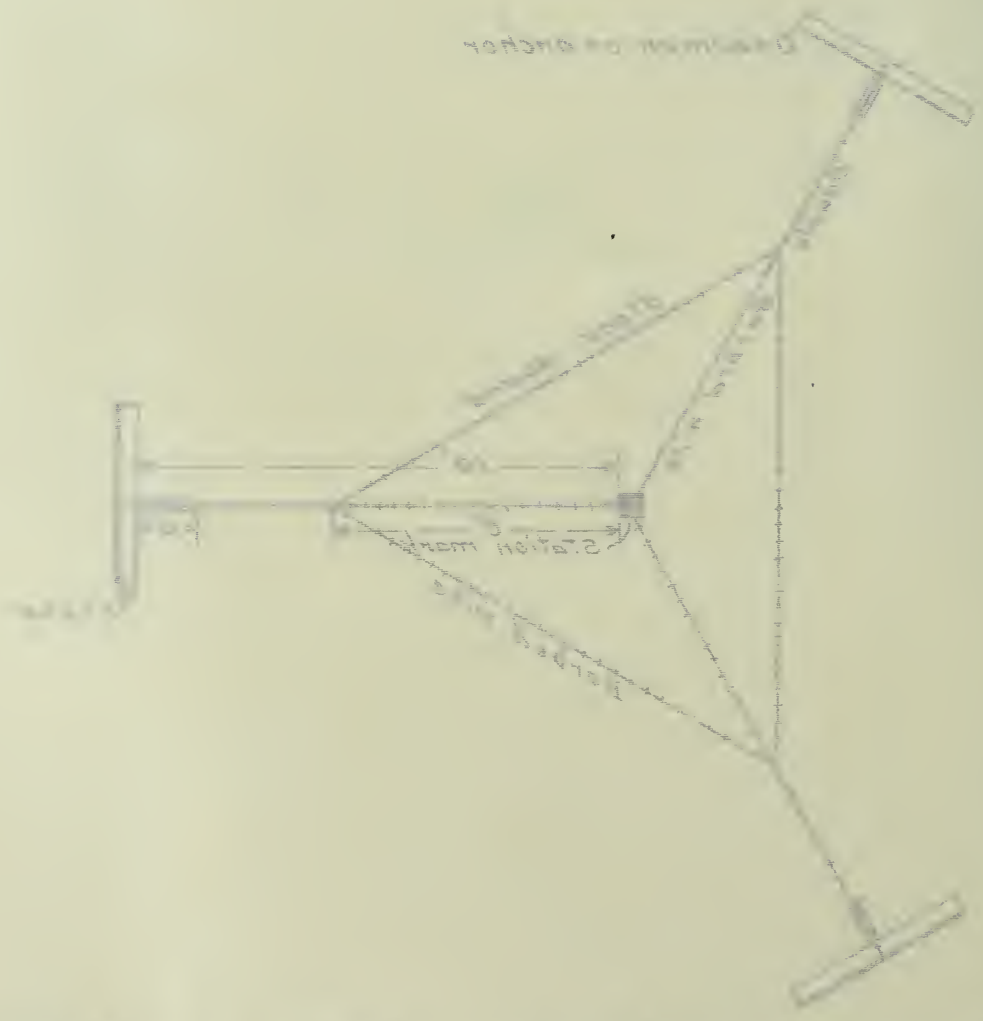
Vertical Projection

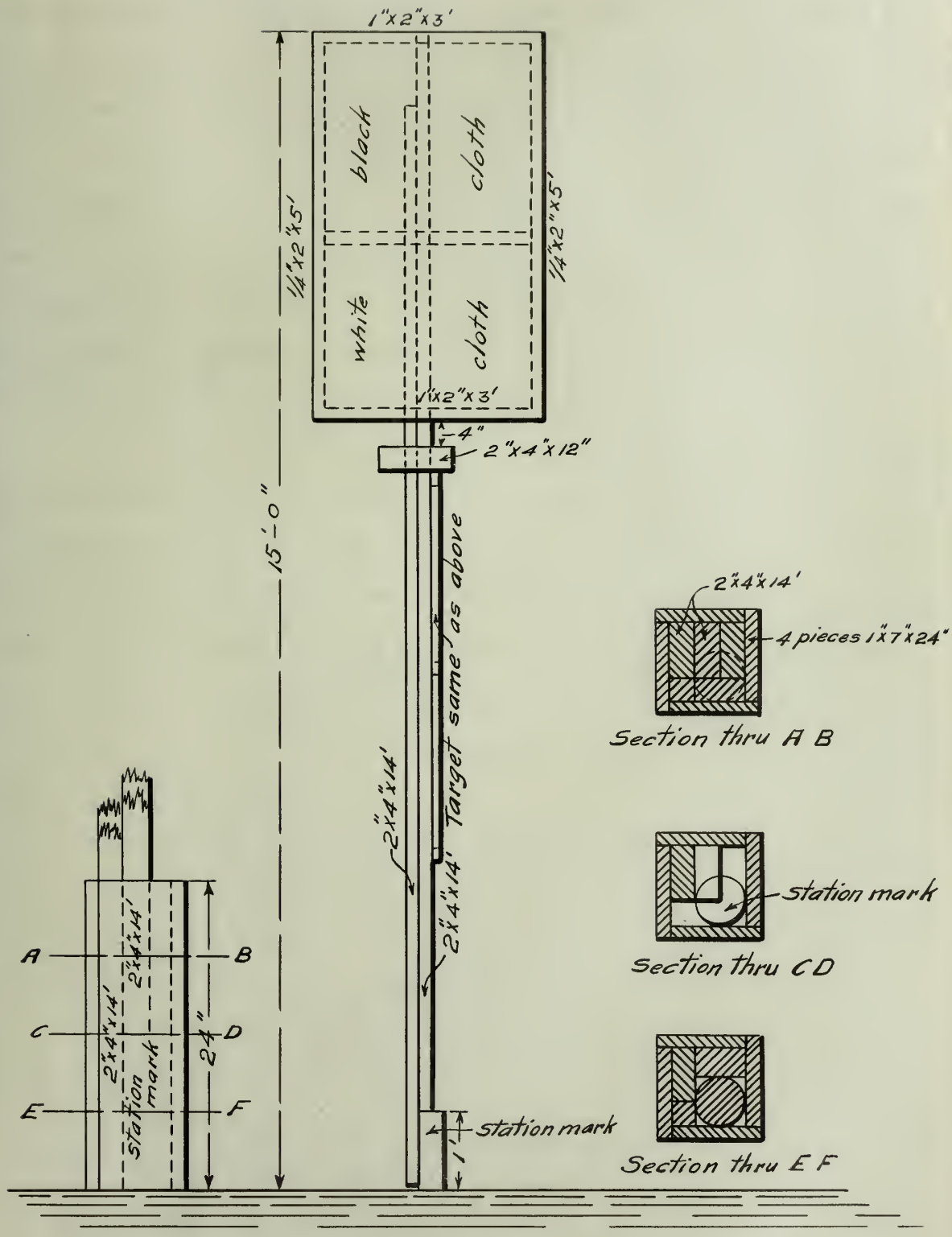


Standard iron post set for station mark.

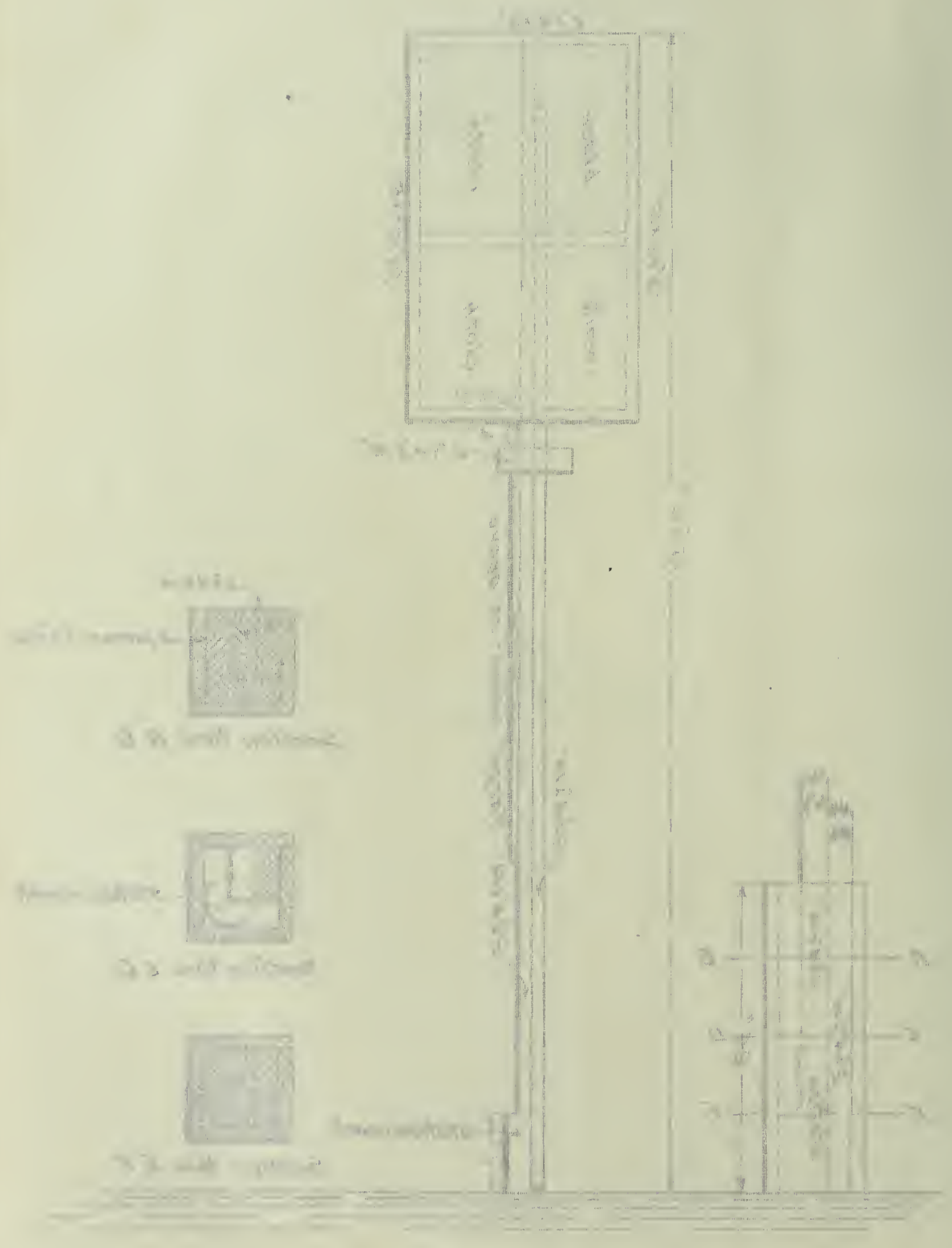


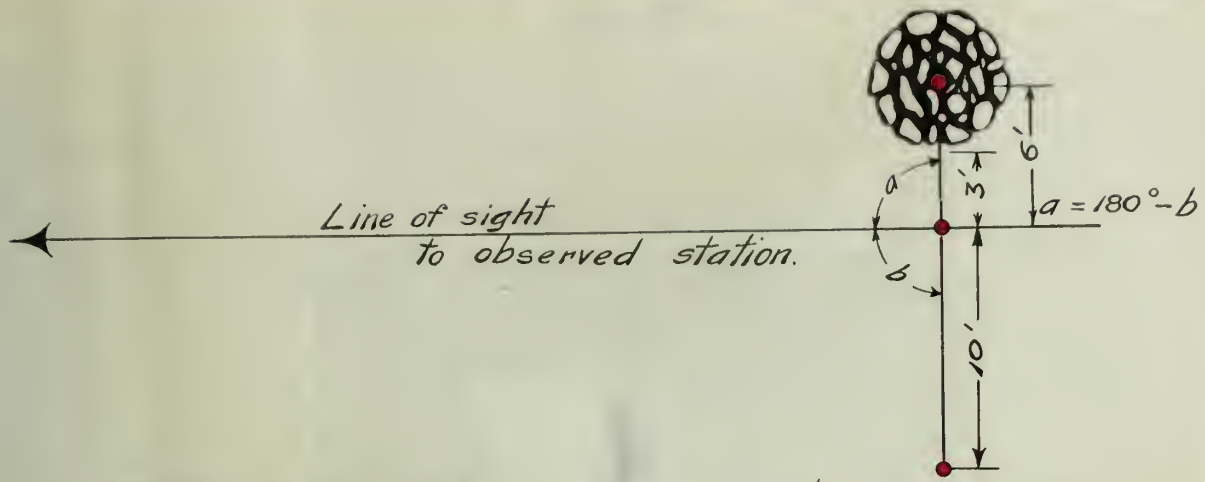
Horizontal projection of sawed timber signal showing position of deadman, guywires and station mark.



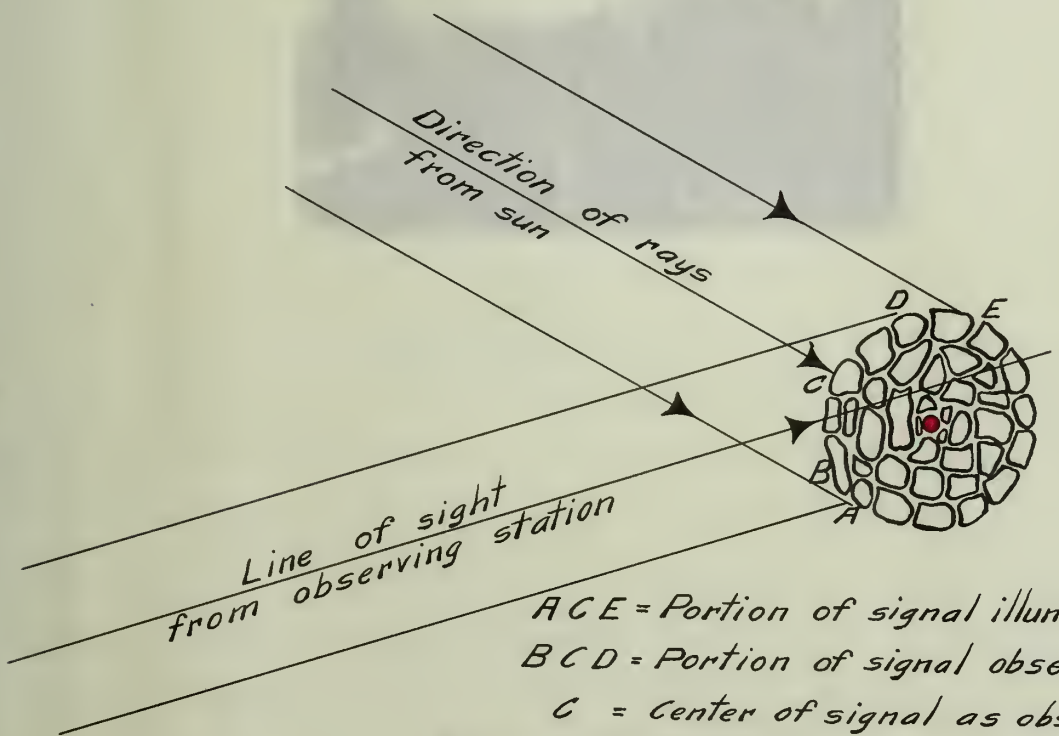


Detailed drawing of a Sawed Timber Signal.



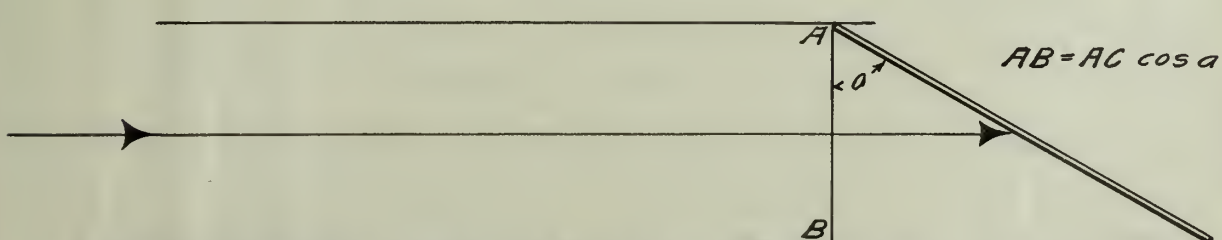


Method of arranging reference points so that either can be used as an off center station.

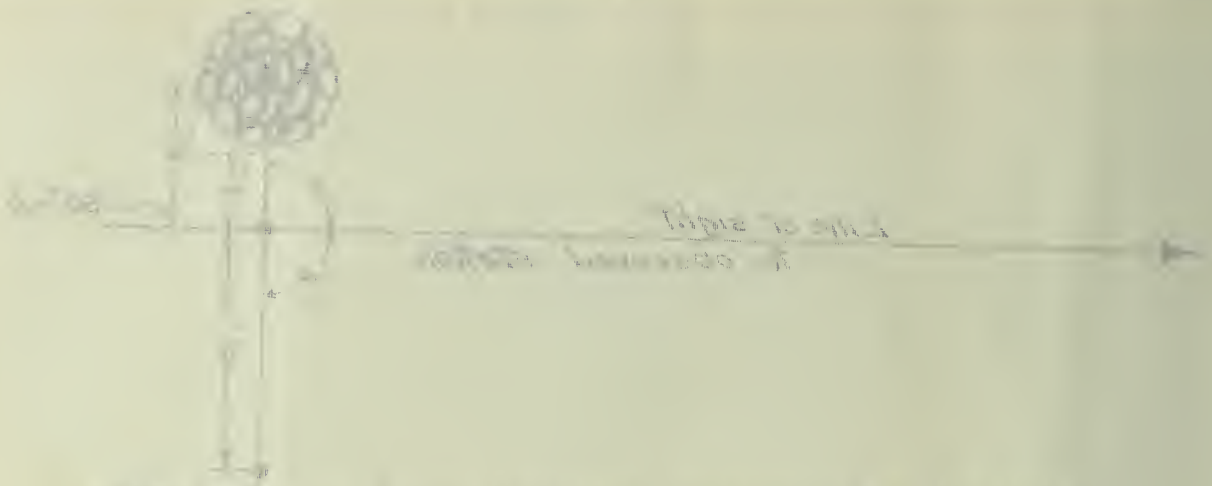


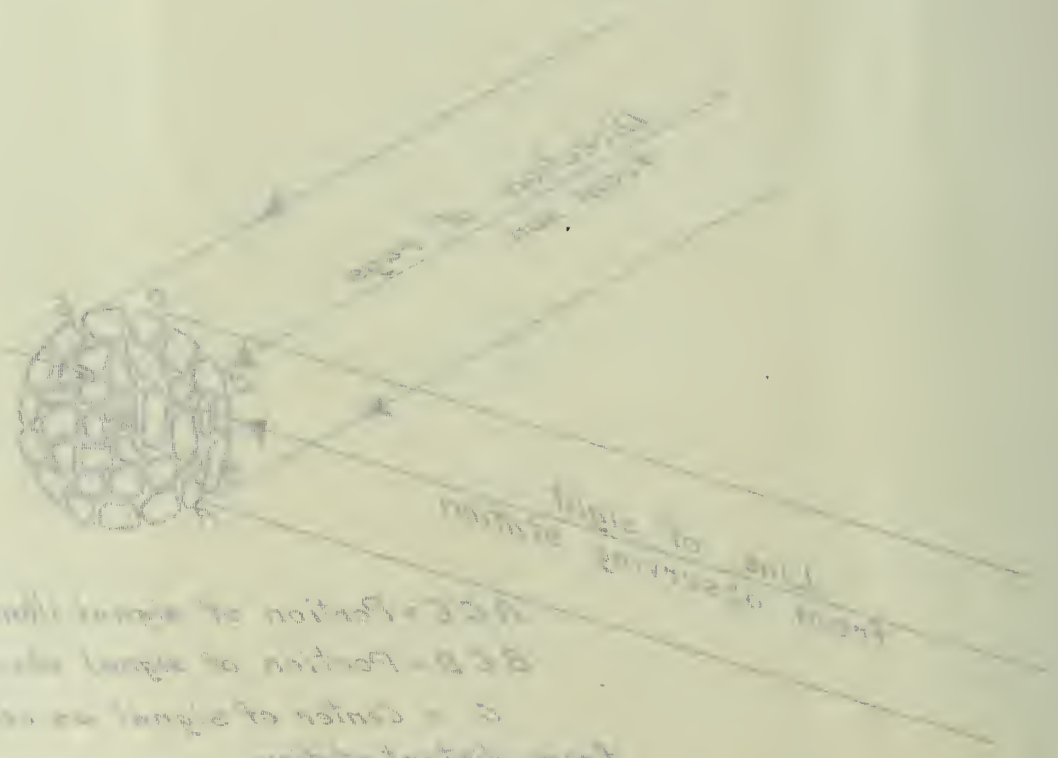
A C E = Portion of signal illuminated.
B C D = Portion of signal observed.
C = Center of signal as observed from distant station.

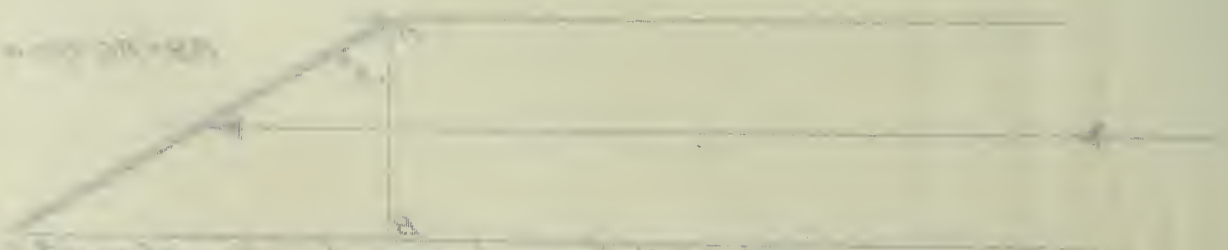
Sketch showing error due to observing an illuminated signal when line of sight is not parallel to suns rays.

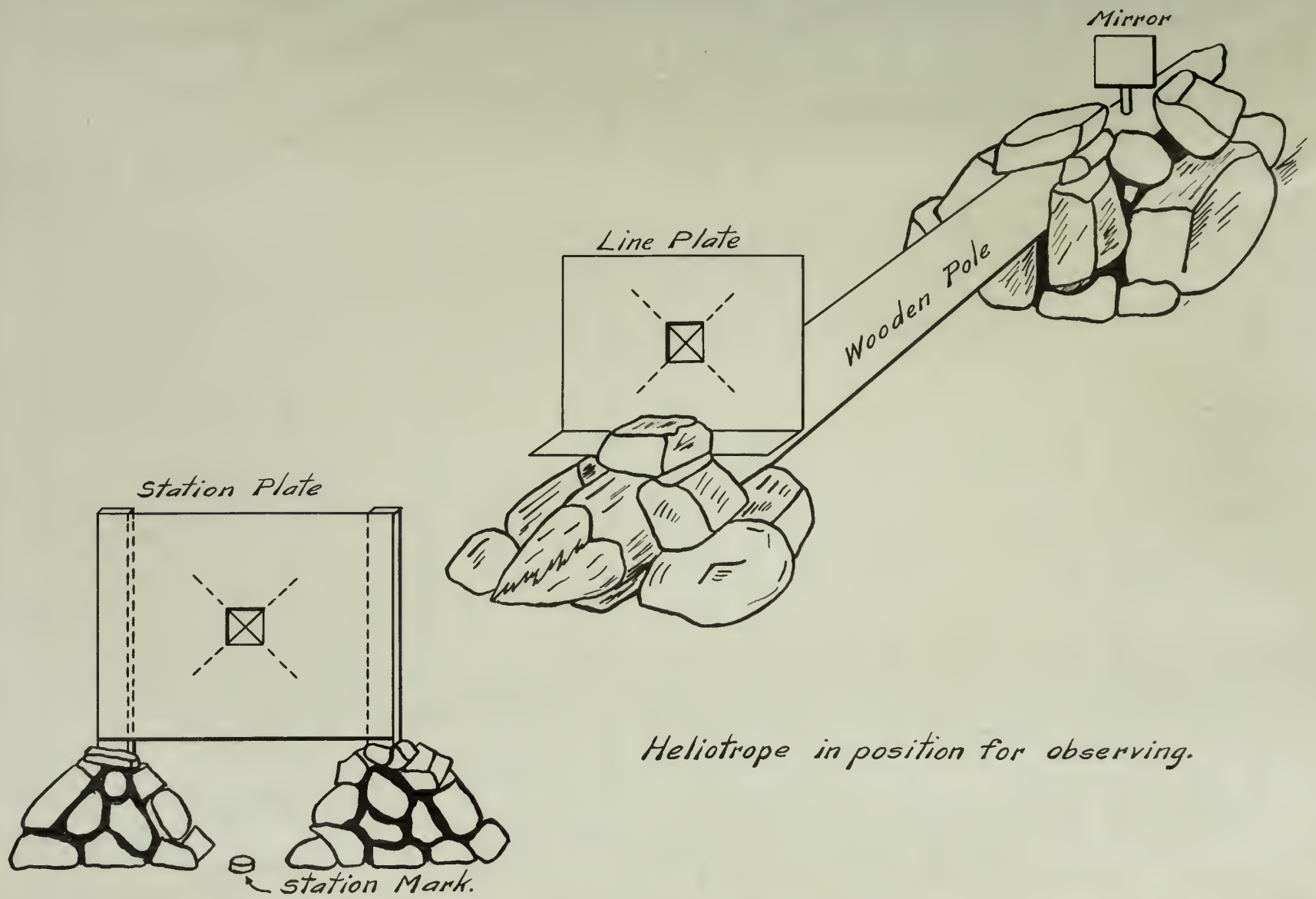


Sketch showing width of flat signal seen when line of sight is inclined to face of signal.

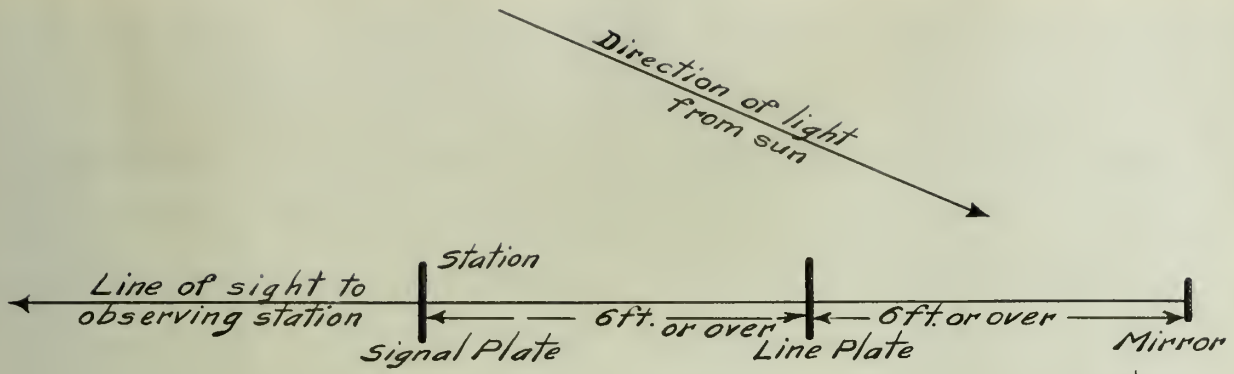




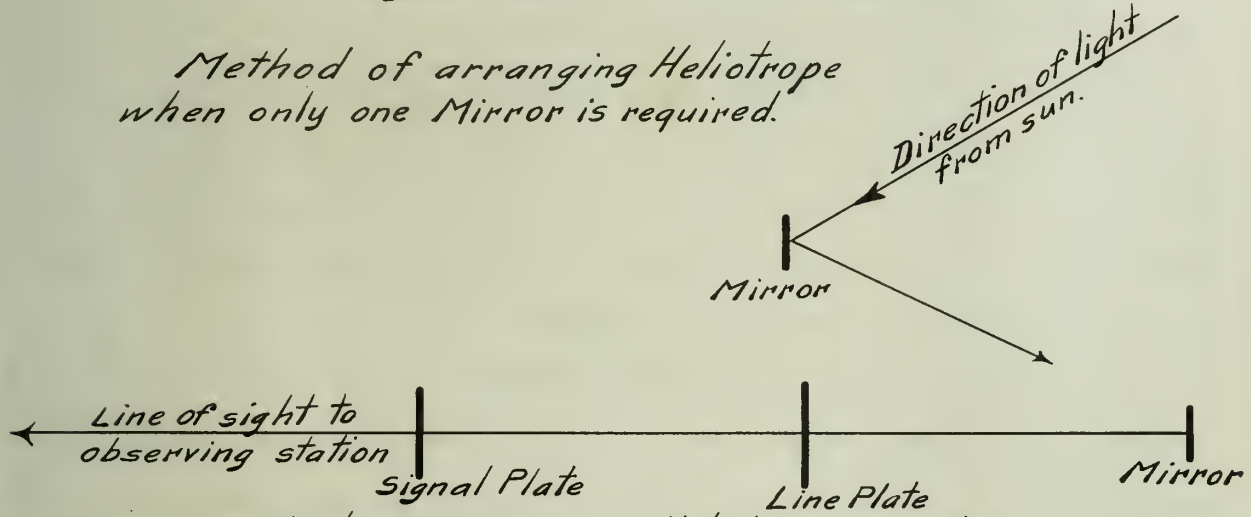




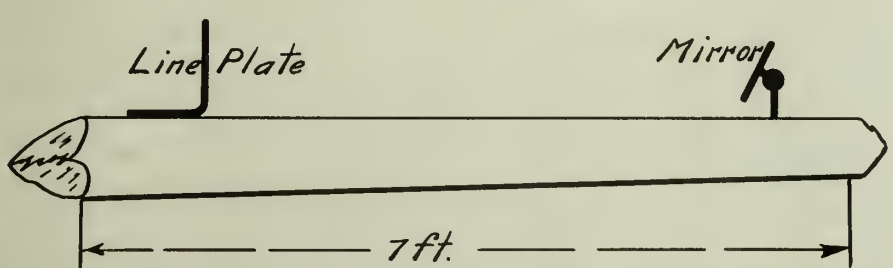
Heliotrope in position for observing.



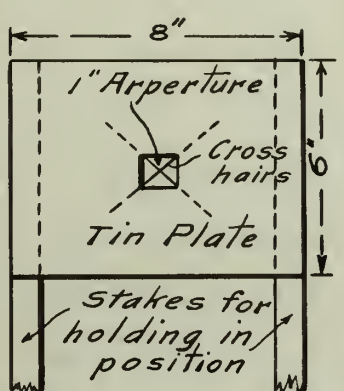
Method of arranging Heliotrope when only one Mirror is required.



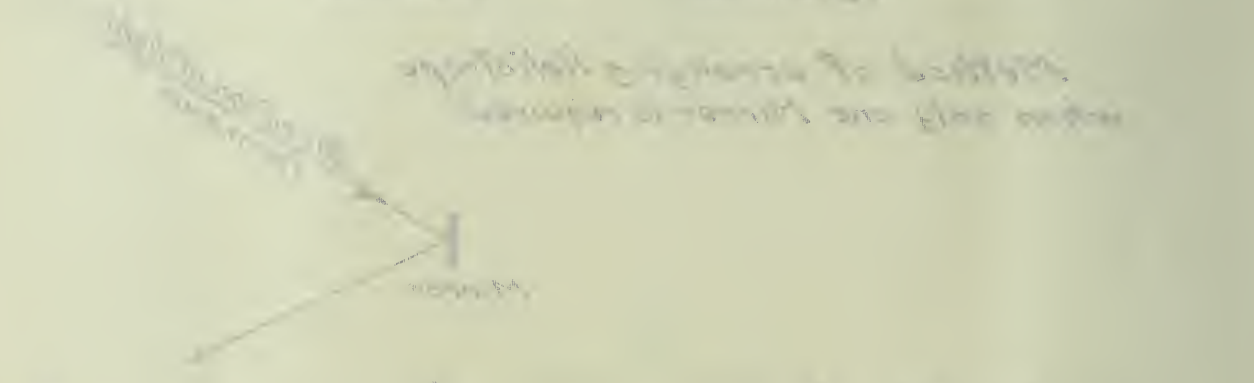
Method of arranging Heliotrope when two Mirrors are required.

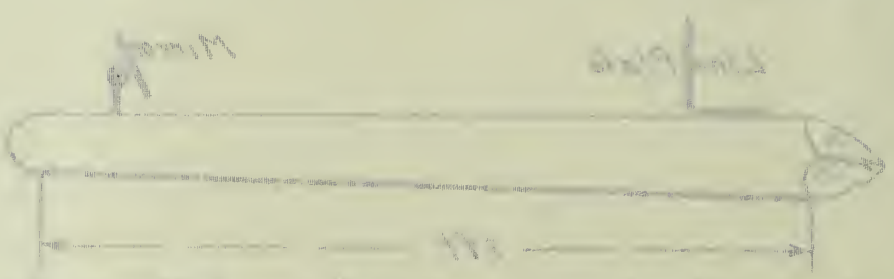


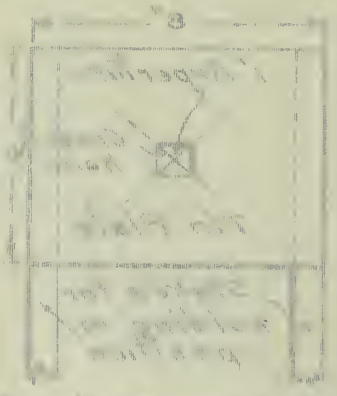
Method of attaching Line Plate and Mirror to one pole.



Details of Signal and Line Plate for Heliotrope.







9—912

DEPARTMENT OF THE INTERIOR,

UNITED STATES GEOLOGICAL SURVEY.

TRIANGULATION FIELD NOTES.

BOOK NO. 2

State, Arizona

Atlas Sheet Chino

Development from Maricopa Astr. Station.

Development from Maricopa Base.

John C. [illegible], *Chief of Party.*

SEASON OF 1903

6—956

Observer.

Recorder.

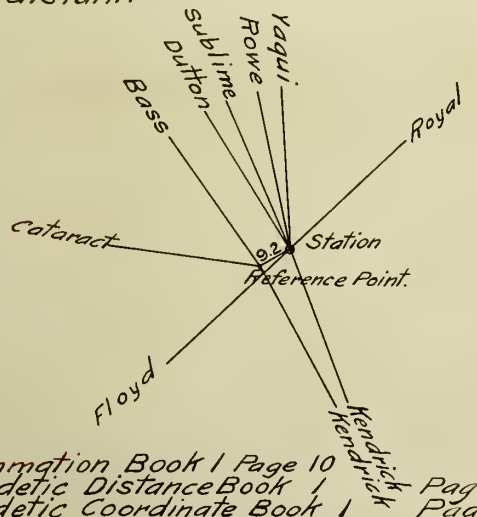
ANGLE

Red Butte Station.

On Red Butte, a prominent flat-topped mountain about 15 miles southeast of Bright Angel Hotel. Summit cleared except on the south, east and southwest part, where some timber still stands. A wagon road runs from Rain Tank around the foot of mountain on east side.

Station mark: A bronze triangulation tablet cemented in malpais rock near the center of the butte and under a rock cairn 6 feet high and 6 feet in diameter.

2 reference points each 1" holes drilled in rock in line with center of station, 9.2 feet and 23.7 feet distant.



Summation Book 1 Page 10
Geodetic Distance Book 1 Page 3
Geodetic Coordinate Book 1 Page 3

69

Station Occupied, Red Butte

Date, Sept. 25 1903

Observer, John T. Stewart.

Recorder, T.S. Chapin.

Objects Sighted	Microm A.			Microm B			Mean.			Angle			Adjusted Angle	
	°	′	″	°	′	″	°	′	″	°	′	″	″	
Kendrick	0	35	0	180	35	01	0	35	01					Time 5-10 P.M.
Cataract	147	54	12	327	54	12	147	54	24	147	19	23	23.0	
Bass	174	11	17	354	11	17	174	11	34	173	36	33	33.0	
Kendrick	0	35	10-01	180	35	00	0	35	01	0	00	00	0.0	
Kendrick	180	36	14	0	36	15	180	36	29	359	59	57	0.0	
Bass	354	12	32	174	12	32	354	13	04	173	36	32	34.0	
Cataract	327	55	28	147	55	28	327	55	56	147	19	24	25.0	
Kendrick	180	36	15	0	36	17	180	36	32					
	216	10	04	36	10	05	216	10	09					
	3	29	15	183	29	14	3	29	29	147	19	20	19.7	
	29	46	23	209	46	23	29	46	46	173	36	37	36.4	
	216	10	04-05	36	10	05	216	10	10	0	00	01	0.0	
	36	09	06	216	09	06	36	09	12	0	00	0	0.0	
	209	45	22	29	45	21	209	45	43	173	36	31	31.0	
	183	28	17	3	28	17	183	28	34	147	19	22	22.0	
	36	09	06	216	09	06	36	09	12					
	71	40	10	251	40	11	71	40	21					
	218	59	21	38	59	20	218	59	41	147	19	20	19.3	
	245	16	29	65	16	28	245	16	57	173	36	36	34.6	
	71	40	11	251	40	12	71	40	23	0	00	02	0.0	
	251	41	19	71	41	21	251	41	40	0	00	03	0.0	
	65	18	06	245	18	06	65	18	12	173	36	35	33.0	
	39	00	32	218	00	33	39	01	05	147	19	28	27.0	
	251	41	19	71	41	18	251	41	37					Time 5-40 P.M.
Kendrick	151	40	13	331	40	12	151	40	25					
Center of Sta	196	40	—	16	40	—	196	40	—	45	00			Distance 9.2 feet.
Mt. Emma	294	10	—	114	10	—	294	10	—	142	30			
Mt Logan	297	00	—	117	00	—	297	00	—	145	20			

10

Red Butte Station

Field Book II – Page 68~82

Kendrick ~ Floyd – 76°-02'-11.6"
24.0
12.6
19.4
17.2
08.0
18.2 76°-02'-17.38"
20.0
22.8
17.4
25.4
12.0
12/208.6

" " ~ Cataract 147 – 19 23.0
25.0
19.7
22.0
19.3
27.0 147-19-22.39
23.5 +19.60
22.5 41.99
20.3
21.6
10/223.9

" ~ Bass 173-36-33.0
34.0
36.4
31.0
34.6
33.0 173-36-34.45
36.0 +17.95
36.5 52.40
36.5
33.5
10/345.5

11

Kendrick ~ Dutton 180°-13'-31.8"
38.0
34.8
30.0
34.8
40.2
38.6
37.0 180°-13'-37.18"
41.6
39.0
38.4
36.2
41.2
39.0
14/532.06

" " ~ Sublime 186-21-21.0
12.0
21.5
21.5
23.5
13.5
20.0 186-21-17.75
21.5
15.5
08.5
18.5
14.0
12/213.0

Center of Station Distance 9.2 ft -45-00
Mt Emma 142-30
Mt Logan 145-20

Correction for off center station.

	Kendrick	Cataract	Bass
	315-00	102-19	128-36
Log Sin Ang	9.8494	9.9898	9.8929
a.c. Log Dist	5.2958	5.3100	5.3401
a.c. Log sin 1"	4.7984	4.7984	4.7984
Log of 92	0.9637	0.9637	0.9637
	0.9073	1.0619	0.9951
Cor to Direction	-8.07	+11.53	+9.88
Cor to Angle		8.07	8.07
		+19.60"	+17.95"

DEPARTMENT OF THE INTERIOR.
UNITED STATES GEOLOGICAL SURVEY

COMPUTATION OF GEODETIC DISTANCES.

Book No. I

Development from Maricopa *Base* Line

Triangle No. 1 *to* No 150

Season of 1903

WASHINGTON
GOVERNMENT PRINTING OFFICE.
1896.

6—922

Triangle	Station	Spherical Angles		Plane Angles	Log. Sines
				9.98697	4.89957
	Red Butte	76 - 02 - 17.38	3.03	76 - 02 - 14.35	0.01303
	Kendrick	65 - 43 - 48.54	3.03	65 - 43 - 45.51	9.95981
	Floyd	38 - 14 - 02.87	3.03	38 - 13 - 59.84	9.79160
			9.09	179 - 59 - 59.70	
				Red Butte to Kendrick	4.70420
				Red Butte to Floyd	4.87241
				9.97421	4.87241
	Cataract	70 - 26 - 59.73	2.80	70 - 26 - 56.93	0.02579
	Red Butte	71 - 17 - 24.61	2.80	71 - 17 - 21.81	9.97641
	Floyd	38 - 15 - 40.42	2.79	38 - 15 - 37.63	9.79185
			8.39	179 - 59 - 56.37	
				Cataract to Red Butte	4.69005
				Cataract to Floyd	4.87461
				9.99852	4.69005
	Bass	85 - 15 - 31.40	0.87	85 - 15 - 30.53	0.00148
	Red Butte	26 - 17 - 10.41	0.87	26 - 17 - 9.54	9.64627
	Cataract	68 - 27 - 19.36	0.86	68 - 27 - 18.76	9.96855
			2.60	179 - 59 - 58.83	
				Bass to Red Butte	4.66008
				Bass to Cataract	4.33780

Figure Adjustment in Book page Computed by

DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

COMPUTATION OF GEODETIC CO-ORDINATES

BOOK NO. 1

Development from Maricopa *Base* Line
Geodetic Position Lat 35°-24' *to* Lat 36°-31'
Long 111°-38' Long 112°-43'
Season of 1903

WASHINGTON
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1900

6—1918

Floyd	Kendrick	(1)	268° - 31' - 27.33"
	Floyd	(2)	- 38 - 14 - 02.87
Floyd	Red Butte	(3)	230 - 17 - 24.46
			180 - 22 - 09.79 (45)
			50 - 39 - 34.25 (45)

Geodetic Co-ordinates.

(4)		35° - 23' - 29.88"	Floyd	112° - 43' - 29.30"	(4)
(24)	$\Delta\varphi$	+ 25 - 39.27		$\Delta\lambda$ - 38 - 04.37	(32)
(25)	φ	35 - 49 - 09.15	Red Butte	112 - 05 - 24.93	(33)

Computation for latitude

(5)	log	4.87241	
(6)	" B	8.51119	
(7)	" cos	9.80542	
(8)	" (I)	3.18902	9.90895 Cos φ' (26)
			- .0000098
(9)	"	9.74482	+ 89
(6)	" C	1.25650	- 9
(10)	" sin	9.77218	
(11)	log (II)	0.77350	
(6)	log D	2.3672	35° - 36' - 19.5" (35)
(16)	" (I+II	6.3812	
(17)	log (III)	8.7484	
(6)	log E	6.0117	F 0.076
(18)	" sin²	9.5170	7.877 (40)
(19)	" (I)	3.1890	7.953
(20)	log (IV)	8.7177	+ .009"

Computation for longitude

log		4.87241	(5)
	m	9.88609	(7)
	A	8.50922	(69)
	sec φ	0.09105	(27)
		- 09	(28)
log	V	3.35877	(29)
		2284.37"	(30)
Δ		- 38' - 04.37"	(31)

Computation of azimuth

log	(V)	3.35877	(34)
	m ($\frac{\Delta\lambda''}{\Delta\varphi''}$)	9.76507	(36)
	c ($\frac{\Delta\lambda''}{\Delta\varphi''}$)	0.00000	(37)
log	(VI)	3.12384	(38)
		1329.970"	(39)
		.009	(41)
		1329.979"	(42)
		+ 22' - 09.79	(43)

(12)	(I)	1545.321	-
(12)	(II)	5.936	
	[I + II]	1551.2	(13)
(21)	(III)	.056	log " 3.1906 (14)
(21)	(IV)	.052	+
	[I + II]	6.3812	(15)
(22)		1539.277"	
(23)	$-\Delta\varphi$	25' - 39.27"	

Computation of Azimuth in Book 1 page 47 Season 1902

Spherical angle and distance in Book 1 - 3

Station Computed

Azimuth a:	Kendrick - Floyd	89° - 01' - 48.55"
Spherical Angle:	Kendrick	+ 65 - 43 - 48.54
Azimuth a': $\Delta a + 180°$	Kendrick - Red Butte	154 - 45 - 37.09
		179 - 51 - 39.47
Azimuth (a):	Red Butte - Kendrick	334 - 37 - 17.56

Geodetic Co-ordinates.

	LATITUDE.		LONGITUDE
φ:	35°-24'-24.83"	Kendrick (Geo. Pos. No.)	λ: 111°- 51'- 05.35"
$\Delta\varphi$	24 - 44.37		$\Delta\lambda$ + 14 - 19.60
φ'	35 - 49 - 09.20	Red Butte (Geo. Pos. No.)	λ' 112 - 05 - 24.95

Computation for latitude:

Kendrick to Red Butte

log. s	4.70420	
" B	8.51119	
" cos a'	9.95642	
		9.90895 Cos. φ'
log. (I)	3.17181	
log. s^3	9.40840	
" C	1.25674	
" $\sin^2 a'$	9.25962	
log. (II)	9.92476	
log. D	2.3673	35°- 36'- 47.02"
" [I+II]^3	6.3441	
log. (III)	8.7114	
		8.802
log. E	6.0120	7.877
" $s^3 \sin^2 a'$	8.6680	6.679
" (I)	3.1718	0.0004
log. (IV)	7.8518	

Computation for longitude:

log. s	4.70420
" sin a'	9.62981
" A'	8.50922
" sec. φ'	0.09105
	-33
log. (V)	2.93428
	859.560
$\Delta\lambda$	14 - 19.60"

Computation of azimuth:

log. (V)	2.93428
" sin. $\left(\frac{\varphi+\varphi'}{2}\right)$	9.76515
" sec. $\left(\frac{\Delta\varphi}{2}\right)$	0.00000
log. (VI)	2.69943
	500.533
$-\Delta a$	0004
	500.533
	- 8'- 20.53"
	179°- 51'- 39.47"

Azimuth check.

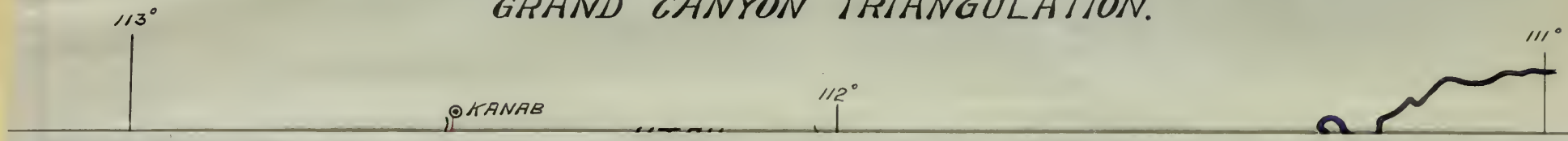
(I)	1485.276 -	
(II)	.841 +	
		[1 + II] 1486.11
(III)	.051 +	log. " 3.17205
(IV)	.007 +	" [1 + II]^2 6.34410
	1484.377"	
$-\Delta\varphi$	24'-44.37"	

	360°- 00'- 00"
	334 - 37 - 17.56
	50 - 39 - 34.25
Check:	76 - 02 - 16.69
Spher. angle	76 - 02 - 17.38
at Red Butte.	

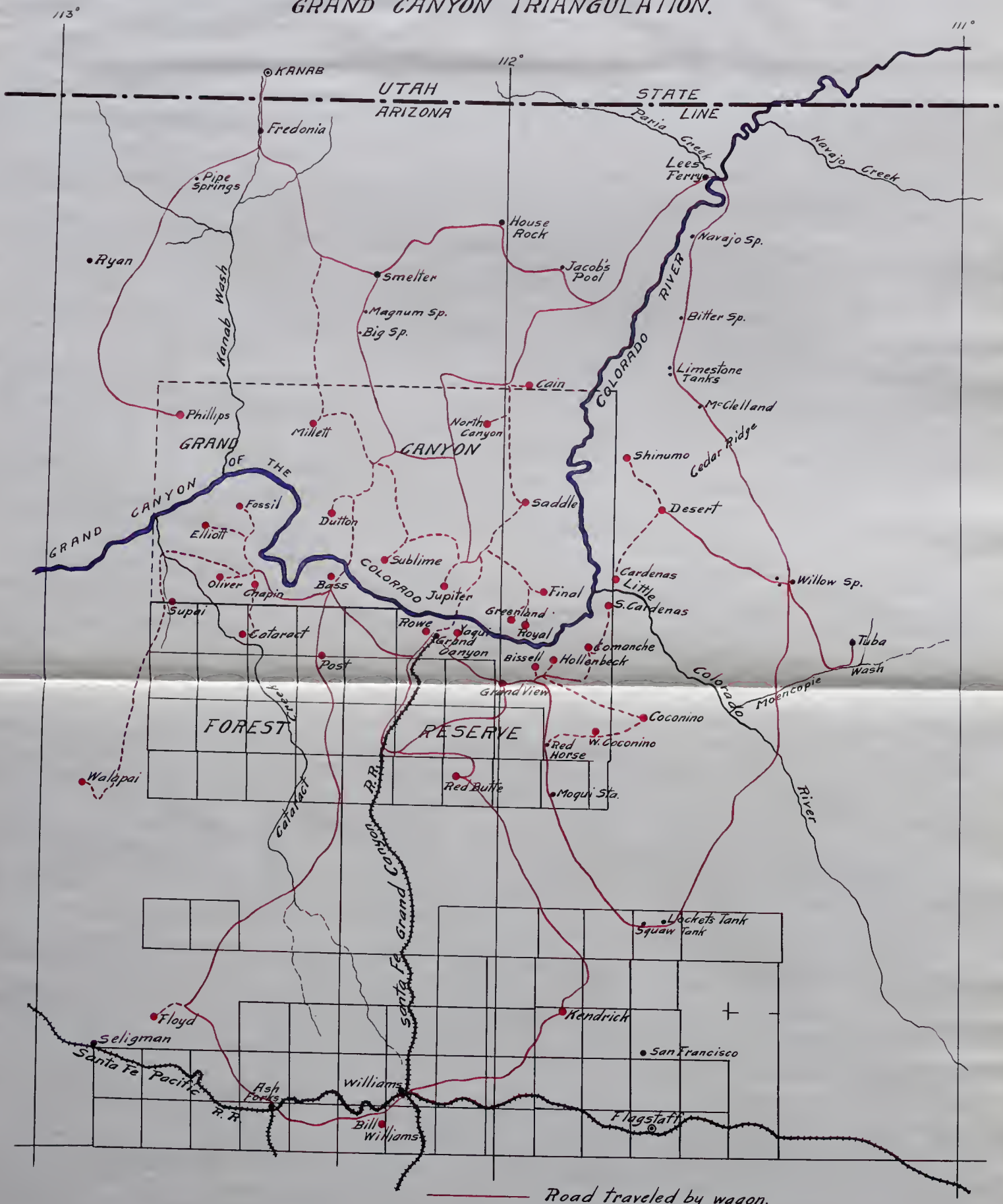
Computation of Azimuth a, in Book page
Spherical angle and distance = s, in Book page, Triangle No.
Station; Computed by

6—1018

MAP SHOWING ROADS AND TRAILS TRAVELED IN THE GRAND CANYON TRIANGULATION.



MAP SHOWING ROADS AND TRAILS TRAVELED IN THE GRAND CANYON TRIANGULATION.



Road traveled by wagon.

Trail traveled by Pack train.

Scale 1 in. = 12 mi.

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